instruction manual

MDITC

BERKELEY
EVENTS-PER-UNIT-TIME-METER

Model 554

Beckman® / *Berkeley Division*

INSTRUCTION
MANUAL

Lot 26 and up
Serial 2155 and up

MDITC

BERKELEY
EVENTS-PER-UNIT-TIME-METER

Model 554

BERKELEY division of
Beckman Instruments, Inc.

Richmond 4, California
15 February 1954

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Subject to the exceptions and upon the conditions specified below, the Company agrees to correct, either by repair, or, at its election, by replacement, any defect of material or workmanship which develops within one year after delivery of the instrument to the original purchaser by the Company or by an authorized representative, provided that investigation and factory inspection by the Company discloses that such defect developed under normal and proper use.

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(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate. Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, Berkeley division of Beckman Instruments, Inc., Richmond 4, California.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

Berkeley reserves the right to make changes in design at any time without incurring any obligation to modify equipment previously purchased to conform to subsequent design changes.

BERKELEY DIVISION
BECKMAN INSTRUMENTS, INC.

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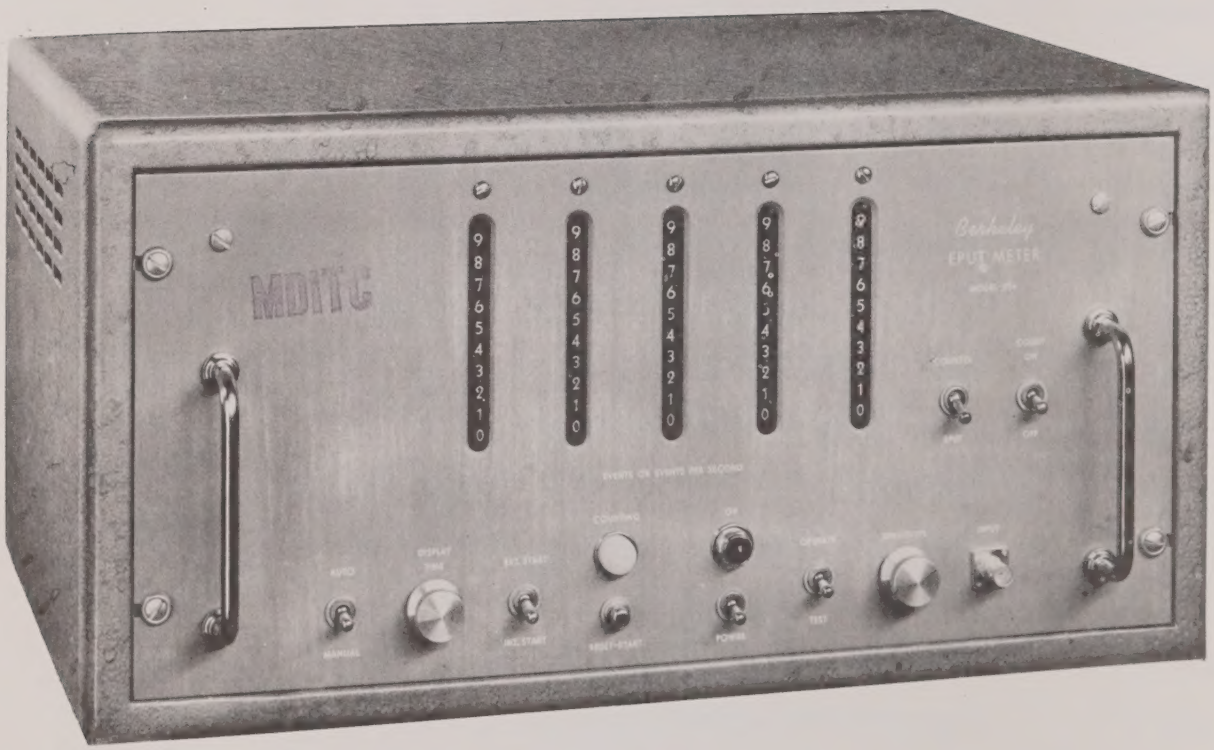

Figure 1. Model 554 Events-Per-Unit-Time Meter.

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Section 1
INTRODUCTION

Purpose and Basic Principles

The Berkeley Events-Per-Unit-Time (EPUT) Meter, Model 554, is a high-speed electronic counter combined with an accurate, crystal controlled timing gate. The unit will automatically count and display in decimal form any number of events from 20 to 100,000 which have occurred during a precise one-second counting interval. The events may be any optical, physical or electrical occurrences translatable into voltage changes. These changes in voltage are amplified, shaped, and conducted to an electronic gate. When the gate is opened by a time base at the beginning of the counting interval, the input signals are transmitted to the five Decimal Counting Units (DCUs). After the gate closes, the total number of events received during the counting period is displayed by illuminated numbers on the DCUs. Two switches on the front panel allow the operator to disconnect the time base from the gate and to use the instrument as an ordinary counter. The basic accuracy of the EPUT is essentially ± 1 event for any input frequency. This is the irreducible error of electronic counters and exceeds that of the time base, which is on the order of 1 part in 10^5.

Applications

Tachometry. The Events-Per-Unit-Time Meter has found broad application as an electronic tachometer where it is used to obtain accurate measurements of high speed rotating machinery. A tachometer pickup may be used to produce signals which are fed directly to the EPUT. The design of this tachometer pickup in itself provides great flexibility. For instance, if a pickup is used to generate one signal per revolution, the EPUT will read directly in revolutions per second. If the tachometer pickup is designed to produce 60 signals per revolution, the EPUT will then read directly in revolutions per minute.

Advantage may be taken of the counting capacity of the EPUT and the flexibiltiy of design of the tachometer pickup to greatly increase accuracy where the total number of rps or rpm at which the equipment is operating does not approach the maximum capacity of the EPUT. Thus, if the tachometer pickup is designed to produce 100 signals per revolution, the

Table 1

REFERENCE DATA

Frequency Range	20 to 100,000 cycles per second.
Counting Period	1 second, ± 0.001%.
Display Time:	Continuously variable from less than one second to about eight seconds.
Input Sensitivity	The input amplitude is adjustable. Maximum sensitivity is greater than 0.2 volts RMS.
Self-checking	A 100 kc signal from the time base can be used to check the operation of the entire circuitry without the use of other test instruments.
Accessory Sockets	The 10-pin accessory socket on the rear chassis permits operation from a remote location and provides unregulated +310 volts, +100 volts, -150 volts, 6.3 volts a-c, and regulated +180 volts. There is a direct connection to the input amplifier. The 6-pin accessory socket on the rear chassis provides control functions to the Berkeley Digital Recorder System which provides a permanent printed record of the visually displayed information. Use of the Recorder System requires no change in operating procedure.
Power Requirements	105-130 volts, 50-60 cycles, 175 watts.
Input Requirements	A periodic wave with a high signal-to-noise ratio, and with an amplitude of 0.2 to 50 volts RMS in the case of sine waves. A blocking condenser between the front panel input and the amplifier will permit connection of voltages up to 600 volts d-c. Direct connection to the amplifier grid is available at the accessory socket for phototubes.
Dimensions	20-3/4" by 10 1/2" by 15".
Weight	Approximately 68 lbs.

counter itself will read directly in hundredths of a revolution and since the basic accuracy of the system is ±1 cycle of the "EPUT" Meter, the accuracy of the results obtained then becomes ±1/ 100th of a revolution.

The advantages offered by flexibility in design of the tachometer pickup can be extended to meet a great variety of individual requirements.

Secondary frequency standards. By making use of the high accuracy of the "EPUT" Meter, ordinary laboratory variable frequency oscillators of sufficient stability can be converted into secondary frequency standards at any frequency from 20 to 100,000 cps. The dial calibration of the oscillator need not be accurate, since the counter measures the frequency. Thus, the usefulness of relatively inexpensive laboratory oscillators is extended. The frequency setting of the time base oscillator must, of course, be initially set to the desired accuracy.

FM-FM telemetering. The "EPUT" Meter is especially useful for calibration of frequency modulated sensing elements used in telemetering systems. The instrument can also be used for recording FM telemetered information (when photographic recording equipment is used). It gives high accuracy where discontinuous readings are feasible.

Frequency characteristic measurement. The "EPUT" Meter is useful for rapid and accurate determination of the characteristics of frequency-dependent networks such as filters and resonant circuits. The speed of measurement attained makes the instrument valuable as a production test tool.

These are but a few of the more general applications of the Model 554. There are a great many interesting and unique applications such as ballistics studies, the determination of elastic constants of materials by measuring natural frequencies of vibration, and others that do not permit detailed descriptions because of their infinite variety. The facilities of our Engineering Department are available to assist you in adapting this versatile instrument to your particular requirements.

Section 2
OPERATION

Installation

No special installation instructions are necessary for the Model 554. A clearance of several inches should be allowed on the top and sides of the unit for ventilation. The unit is designed to operate from a power source of 117 volts, 50 to 60 cycles, and draw about 175 watts. Proper operation may be expected over a 105 to 130 voltage range.

Operation

Table 2 and Figure 2 should be consulted for information on control and connector functions.

To check the unit for proper operation, turn on the POWER switch. At first, erratic action (as shown on the DCU's) may occur. This is a normal condition and after a short warm-up period, operation will stabilize. The "On" pilot lamp will light when the unit is receiving power. Make sure the fan is turned on. The switch for the fan is located at the rear of the unit.

Place the AUTO-MANUAL switch in AUTO. The unit will then recycle automatically.

Turn the DISPLAY TIME control completely to the left (counter-clockwise). The display period will be about one second.

Put the EXT. START-INT. START switch in INT. START.

Place the OPERATE-TEST switch in TEST. The unit will now have the 100 kc signal from the time base impressed at the input.

Place the EPUT-COUNTER and COUNT switches in the EPUT and OFF positions.

Adjust the SENSITIVITY control for the correct operating value as shown by the action of the DCU's. The unit should read 00000 (or 00001) after counting for one second. If it doesn't, refer to Section 4 for trouble-shooting procedures. Before assuming that the equipment is not operating correctly, the operator must be sure that he has followed carefully the directions given in sub-paragraphs (1) to (6) above, and that the unit has had sufficient time to warm up. If the unit is found to operate correctly, it is now ready for use.

Operating Procedures

To operate the unit, connect the BNC male connector end of the input cable to the INPUT jack and the other end to any a-c generating equipment whose dc operating level does not exceed 600 volts and whose output is within the operating range of the EPUT (0.2 to 50 volts rms).

Operating the unit as an Events-Per-Unit-Time Meter.- The following switch and control settings should be made:

a. OPERATE-TEST switch. Throw the switch in the OPERATE position.

b. SENSITIVITY control. Adjust the control completely clockwise.

c. EXT. START-INT. START switch. Place the switch in the INT. START position.

d. AUTO-MANUAL switch and DISPLAY TIME control. These can be set to those settings needed by the operator.

e. COUNTER-EPUT switch. Place in EPUT position.

f. COUNT switch. This switch should be OFF.

Operating the unit as a counter. By placing the COUNTER-EPUT switch in the COUNTER position, the Model 554 will operate as a conventional counter, being turned on and off by the COUNT switch.

Table 2

CONTROL AND CONNECTOR FUNCTIONS

Name of Control	Circuit Desig.	Component	Function
AUTO MANUAL	S204	SPST toggle switch	Disables automatic reset.
DISPLAY TIME	R255 R255	Potentiometer	Varies display time of numbers indicated on DCU's.
EXT. START-INT. START	S206	SPDT toggle switch	In the EXT. START position the unit is reset from a remote location.
RESET-START	S205	Microswitch pushbutton	Resets all DCU's when operated.
POWER	S101	DPDT toggle switch	Applies power to instrument.
OPERATE-TEST	S201	SPDT toggle switch	In TEST, a 100 kc signal from the time base is applied to all circuits for test purposes.
SENSITIVITY	R202	Potentiometer	Used for accurate operation in the presence of interference.
INPUT	J201	BNC connector	Increases sensitivity for accurate operation in the presence of interference.
COUNTER-EPUT	S202A & S202B	DPDT toggle switch	In COUNTER, functions as a conventional counter.
COUNT	S202	SPDT	Turns counting circuit on or off in COUNTER.
FAN	S102	SP ST	A switch at the rear of the instrument which turns the cooling fan on and off.

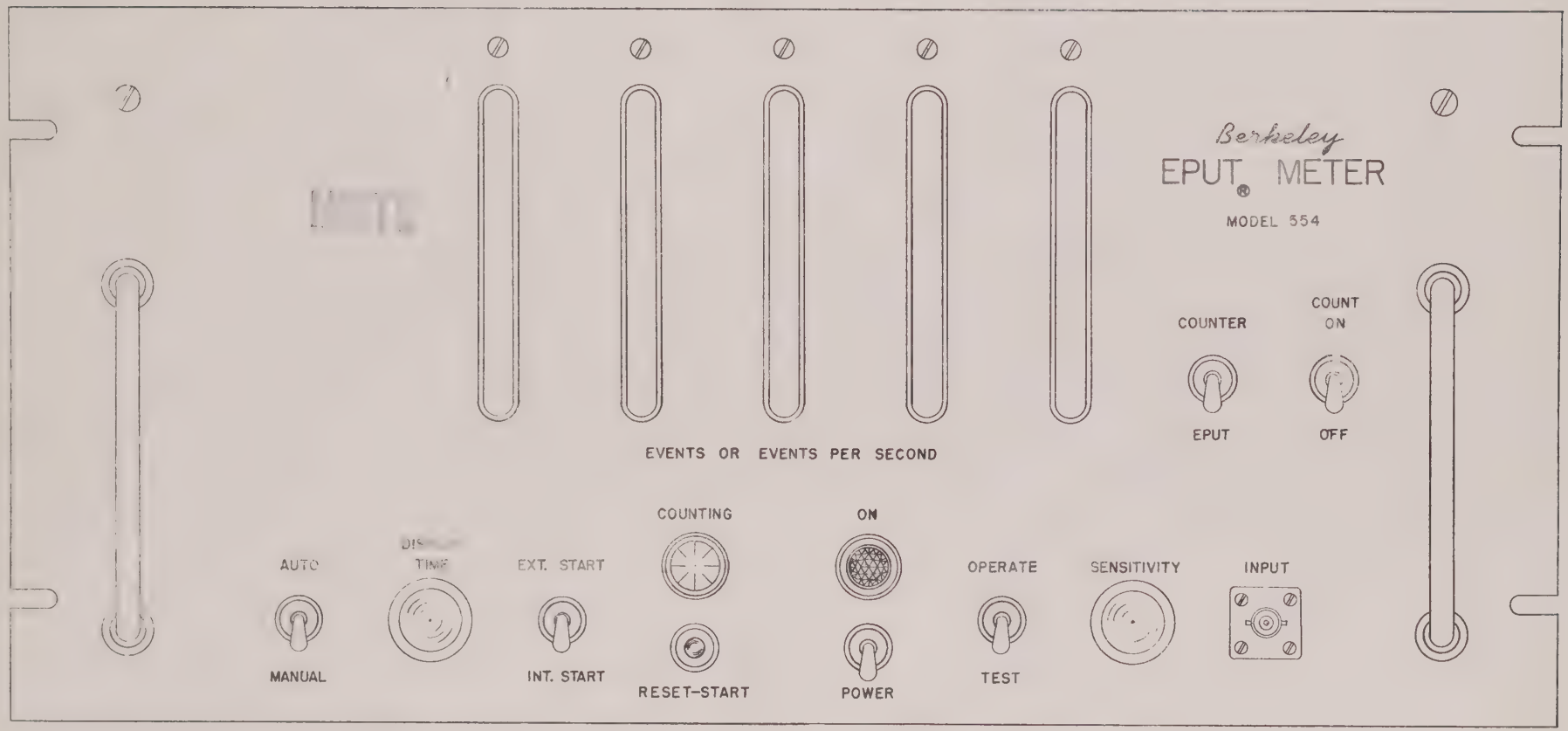


Figure 2. - Front Panel, Model 554 "EPUT" Meter

Scanning for any integral number of seconds.

a. Turn COUNT switch to ON.

b. Place COUNTER-EPUT switch in EPUT position.

c. At the start of a timing period (when the COUNT indicator lamp comes on) throw the COUNTER-EPUT switch to COUNTER position. Start a stop watch at the same instant.

d. When the watch reaches one second less than the desired interval, throw the switch back to EPUT position. This allows the following time base pulse to stop the period. The manual timing interval can be verified by stopping the watch when the switch is returned to EPUT position.

e. The DISPLAY TIME control should be adjusted as desired.

For remote operation, place the AUTO MANUAL switch in the MANUAL position and the EXT. START-INT. START switch in the EXT. START position. The operator must attach a cable to the accessory socket at the rear of the chassis and connect a normally closed switch between the lead to pin D and ground. Opening this switch will reset the unit and it can be used as a reset-start switch. While operated in this manner the unit, after the counting period, will display the summation until reset by the operator. Otherwise the other controls and switches are set as before.

Section 3

THEORY OF OPERATION

General

Basically, the "EPUT" Meter consists of an input circuit, a time base, a gating circuit (including a signal gate and a gate control), an automatic reset, and five decimal counting units (DCU's). For full DCU information, see Appendix A. In addition, there is a power supply which provides all necessary power for the equipment. The simplified block diagram in Figure 3 shows the interconnections and ideal waveforms with the unit in the TEST position. When the unit is in OPERATE, incoming signals are fed to the input circuit where they are amplified and shaped. When the electronic signal gate is opened for precisely one second by the time base, the signals are transmitted to the DCU's, counted, and the summation displayed for a predetermined period while the gate is closed. The auto-reset circuit resets the DCU's to zero and prepares the gating circuit for another counting cycle.

Placing the unit in the TEST position couples a 100 kc signal from the time base into the input circuit. This provides a reliable check on the entire operation of the instrument, for when it is operating correctly the DCU's will display a count of 00000 at the end of each counting period. If such is the case, the only possible source of normal error is the absolute frequency of the oscillator.

Circuit Analysis

Input circuit. There are two input connections to the instrument (see Fig. 11). A BNC connector (J201) is located on the front panel and used for a-c signals, while pin G in the accessory socket (J101) at the rear of the unit is used for devices having a small d-c level output, such as photocells. Both inputs are tied to the grid resistor (R202) of amplifier V201, pin G directly, and J201 through blocking condenser C201. The plate output of V201 is R-C coupled to the grid of the second amplifier, the left-hand side of V202. A portion of the output developed across the plate load resistor, R209, is used as negative feedback to the cathode of V201 to improve stability and reduce "hum". The output is also R-C coupled to the Schmitt Trigger, V203, whose square wave output is differentiated by C208 and R218 and placed on the grid of the signal gate, V204. While this gate is opened for

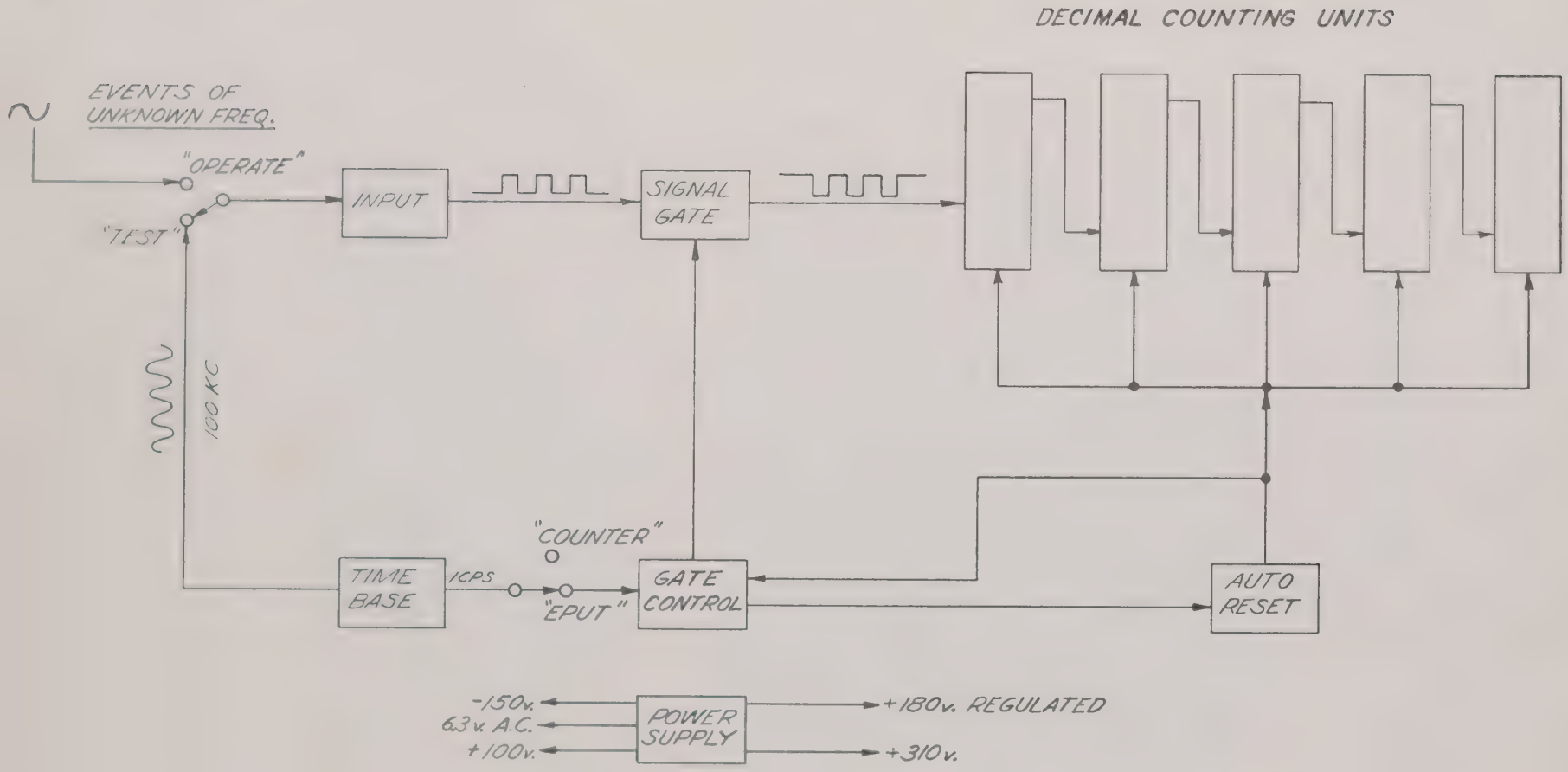


Figure 3. - EPUT Simplified Block Diagram

exactly one second by the time base, pulses are transmitted directly from the plate to the DCU's.

The Schmitt trigger circuit - often called a "voltage discriminator". - has two stable states, the particular state determined by the instantaneous value of the input voltage. When the input voltage is increased above 20 volts, the circuit will be triggered in one direction. Whent the input voltage is decreased below 11 volts, the circuit will be triggered into its other stable state. The difference between the two triggering voltages is termed the hysteresis of the circuit and its value (9 volts in this case) is dependent on the choice of circuit components. Figure 4 shows the circuit with the input a source of voltage whose value can be varied. With no input, V1 is cut off and V2 conducting because the voltage divider effect of R213, R216 and R217 keeps the grid of V2 at about 32 volts, and since V2 acts as a cathode follower, its cathode is also close to 32 volts. The plate of V1 is at 270 volts and that of V2 at 105 volts, As the input voltage is slowly increased, nothing will happen until a point slightly below 20 volts is reached, when V1 begins to conduct. At this point, any small increase in voltage at the grid of V1 appears amplified as a drop in voltage across R213 and is fed to the grid of V2 through the cross-over network consisting of R216, R217, C207 and the grid-to-ground capacitance. The cathodes of V1 and V2 will tend to follow the grid of V2 negative, and V1 will act as a cathode input amplifier with its anode changing in a negative direction in response to the negative cathode signal. This action is regenerative, and the circuit triggers to its second stable state. In this new state, V1 is conducting and V2 cut off. The grid of V2 is now at a negative voltage and that of V1 is about 20 volts. The cathodes are then at about 21 volts, the plate of V1 about 100 volts, and the output plate at 285 volts. Any further increase in input voltage will raise the cathodes and lower the plate potential of V1 and therefore the grid of V2, but will not otherwise affect the state of the circuit. If now the input voltage is decreased to the vicinity of 11 volts, V2 starts to conduct. Also, less current is drawn by V1 so that its plate potential - and the grid of V2 - begins to rise, and a regenerative condition results. The circuit then triggers back to its original state with V2 conducting and V1 cut off. The cyclograms of Figire 5 show the output plate voltage relationships. It should be noted that when the input voltage lies between 11 and 20 volts, the circuit may exist in either of the two states, depending on whether this value was approached from above or below. The "Sensitivity" potentiometer, R202, controls the input voltage to the Schmitt Trigger.

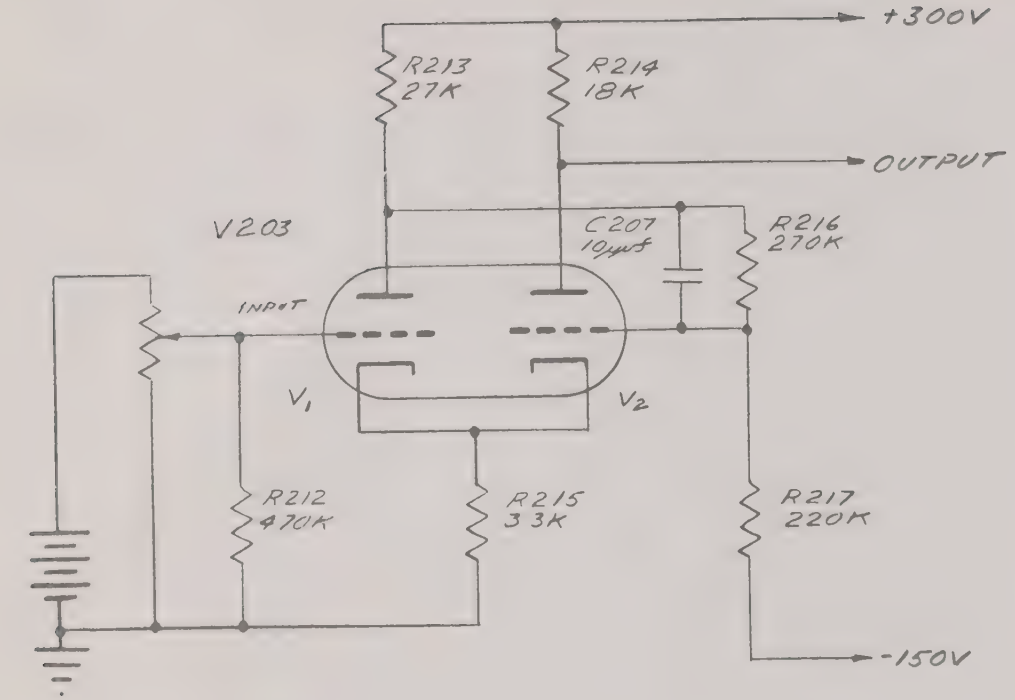


Figure 4. - Schmitt Trigger Circuit

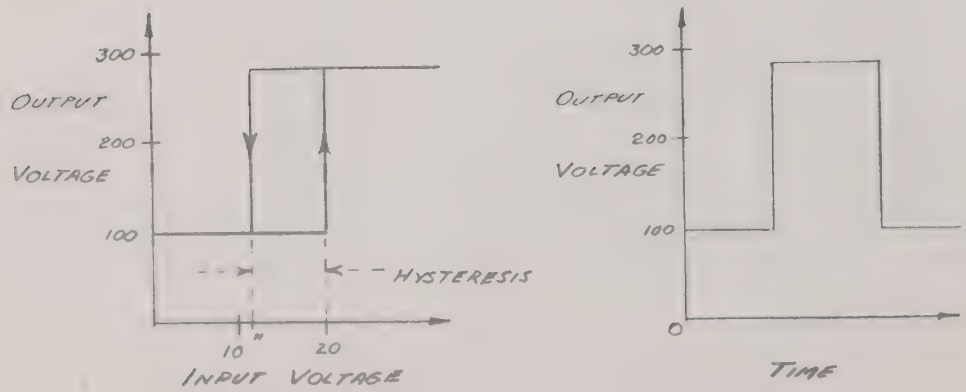


Figure 5. - Schmitt Trigger Cyclograms

Time base. - The time base consists of a 100 kc crystal oscillator (V701), a cathode-coupled shaper stage (V702) which transforms the sinusoidal output of the oscillator into a rectangular wave, and five frequency dividers (V703 to V707) whose function is to divide the oscillator frequency by 10^5 and yield a one-cycle-per-second output to the gating circuit. B+ is 180 volts regulated (see Figure 13).

The time base oscillator circuit consists of a two-stage amplifier with a series-resonant crystal network feedback loop. This system would oscillate even with the crystal (Y701), its series coil (L702), and capacitors C731 and C732 shorted, because any signal which appears on one of the grids is amplified, inverted, and fed in phase so that it reinforces the original signal. The series-resonant crystal network permits only the 100 kc frequency to be effective, since a phase shift is introduced at any other frequency. Also, L701 and C707 are parallel-resonant only at the required frequency. Figure 6 shows the relationship between the frequency and phase-angle of the frequency-determining oscillator components. The amplitude is kept constant through bias developed across R703, while the cathode by-pass capacitors, C704 and C705, tend to eliminate degeneration by maintaining the cathode potentials at steady d-c values.

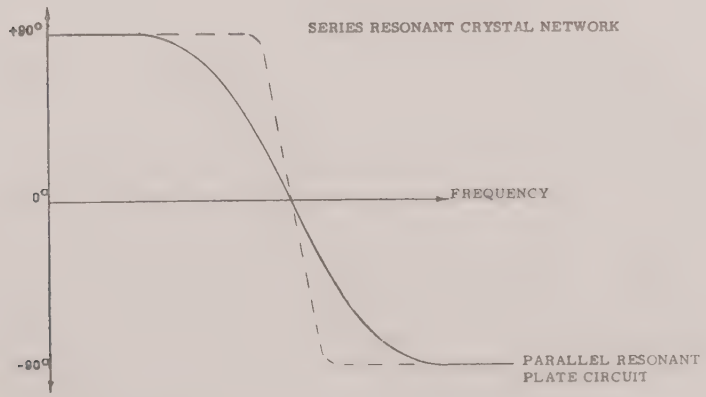


Figure 6. - Oscillator Phase - Frequency Graph

The net result is that the circuit has zero phase-shift, constant amplitude, and a loop gain of one, which fulfills the requirements for an oscillator at 100 kc. Fine adjustment of the oscillator frequency is obtained with the variable capacitor C731, and to a lesser extent by C709.

The time base shaper circuit transforms the sine-wave output of the oscillator into the rectangular wave needed to drive the first divider. The circuit is essentially a one-shot multivibrator whose R-C coupling has a very long time constant compared to the period of the sinusoidal input. The operation, however, is similar to that of the Schmitt Trigger explained above, since the input signal forces the tube to recover long before C710 has a chance to recharge through R716.

Frequency Dividers. The five dividers and one-shot multivibrators divide the oscillator frequency by 10^5, each divider performing a division by 10. The first divider stage, V703, shows that with no input from the clipper, this stage is in a stable state in which the left-hand triode is cut off, while the right is conducting since the grid is tied to B+. When the rectangular output of the clipper is applied to the first divider, the positive rise of the wave produces no change in the state. The negative portion, however, is coupled to the right-hand grid through coupling capacitor C714. This negative swing in grid potential cuts off the right-hand triode and results in a rapid rise in plate voltage which is coupled to the left grid through the cross-over network consisting of R714, R761, C712, and the grid-to-ground capacitance. The increase in left-grid potential causes the left triode to conduct. V703 now exists in a quasi-stable state with the left side conducting and the right cut off. The duration of this condition is dependent on the time necessary for C714 to discharge through the series resistances, R721 and R722.

Proper adjustment of potentiometer R721 sets the slope of the recovery curve so that the positive peak of the tenth pulse rises above cut-off, causing the right-hand triode to conduct. By coupling this negative swing of the right plate to the left grid, the system returns to its original stable state. The voltage waveforms at various points of the first divider are shown in Figure 7. The dotted shape at the input pin is the actual wave shape as observed on an oscilloscope and is due to the additive effect of the left-hand plate going positive at the same moment as the positive half of the tenth pulse.

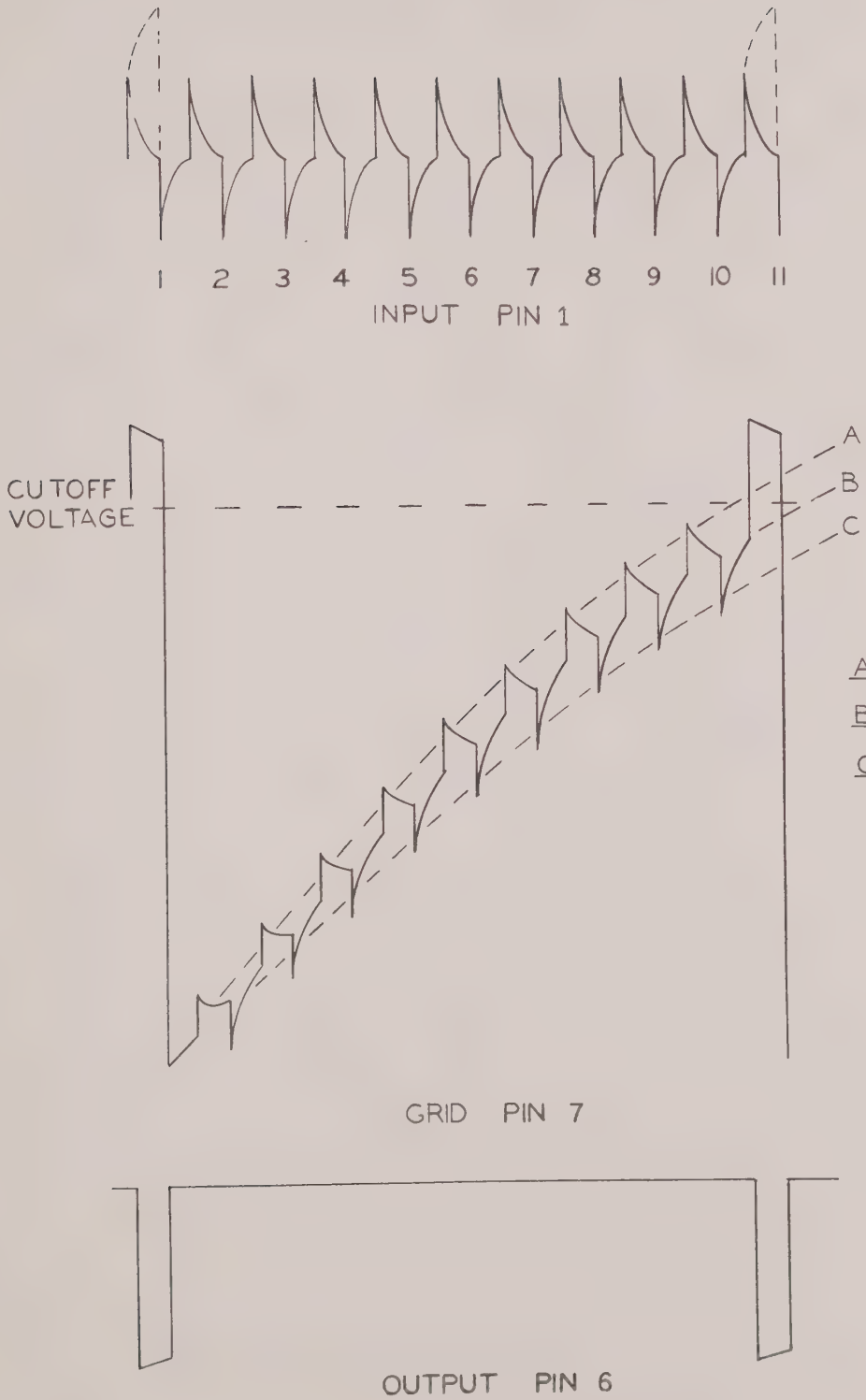


Figure 7. - V707 Voltage Waveforms

The average recovery voltage (base curve) on pin 7 is almost linear, since only about one-third of the recovery time is used. Moving the arm of R721 towards B+ allows division by eleven, while moving it in the opposite direction causes division by nine. The theory of operation of the other dividers is identical except that the duration of the output changes from 5/100 of a cycle at the first divider to 95/1000, 905/10,000, 9095/100,000 and 90905/1,000,000 for the second, third, fourth and fifth dividers, respectively.

Gating circuit. - The output of the time base is coupled to the grid of the time base gate (V206). When the gate is open, the signals are transmitted to the gate control binary (see Figure 11).

The binary used here is a modification of the Eccles-Jordan trigger circuit with two stable states. The circuit is a two-stage, resistance-coupled amplifier with the output of the second stage connected to the input of the first, as shown in Figure 8.

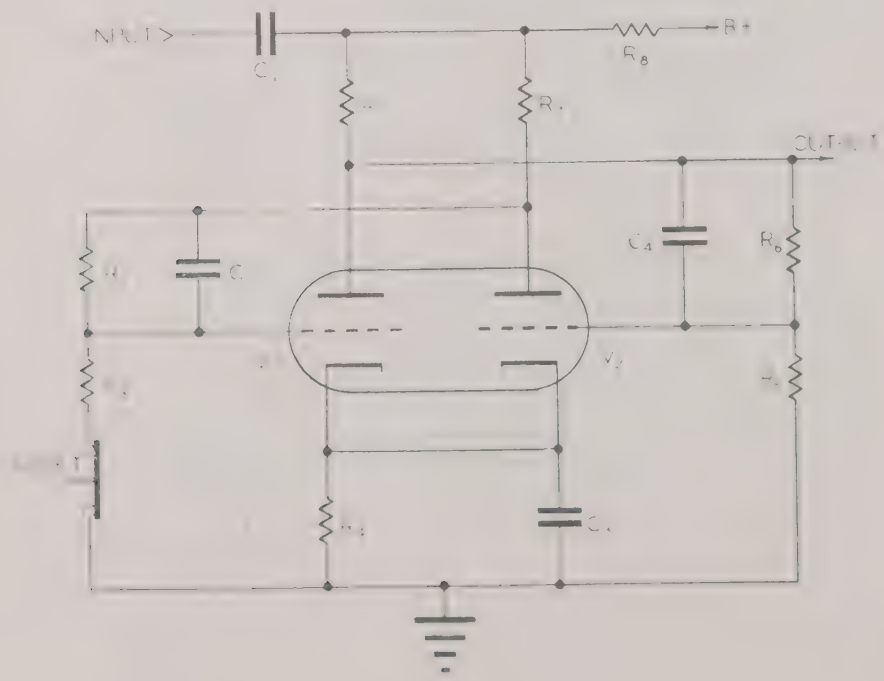


Figure 8. Basic Binary Circuit.

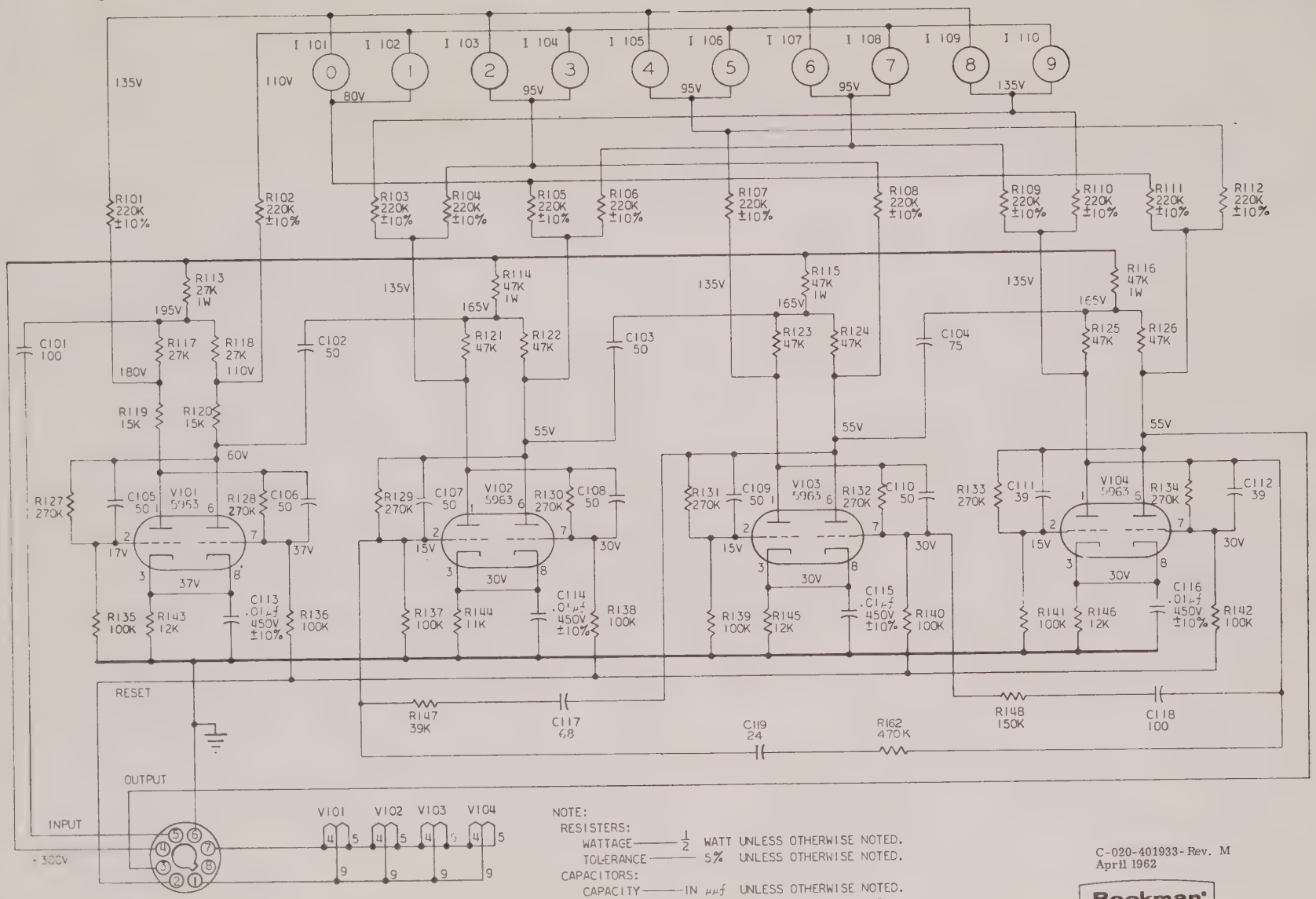
With no input, the loop gain is less than one, and the circuit is in one of its two stabel states, i.e., either V1 conducting and V2 cut off, or V2 conducting and V1 cut off. The circuit is triggered from one state to the other by making the loop gain greater than one. The binary is coupled to a single trigger source through C1 and R8 in such a way that the effect of the trigger is different on the two stages, depending on which stage is conducting. For example, assume that V1 is conducting and V2 cut off. If a negative pulse is applied at the input, there is a drop in the plate voltage of V2. This drop in voltage is transmitted to the grid of V1 through the cross-over network consisting of R2, R3, C2 and the grid-to-ground capacitance of V1. The plate of V1 then starts to rise, carrying with it the grid of V2. When the input pulse is of sufficient amplitude, the loop gain becomes greater than one, and the binary is triggered to its other stable state, V2 conducting and V1 cut off. The next input pulse reverses the process and causes the binary to return to its original state. Thus, the binary completes a cycle for every two input triggers. Opening the reset switch allows B+ to be applied to the grid of V1 and causes the binary to assume the reset condition, V1 conducting and V2 cut off.

After reset, the left-hand sides of V207 and V208, the gate control binary and latching binary, are conducting. Also, since the right-hand plate of V208 is at its most positive value, the suppressor grid of the 6AS6, V206, is at a slightly positive potential and the gate is open. Under these conditions, positive pulses from the time base are amplified and applied to the Gate Control Binary. On the first pulse, V207 becomes right-hand-side conducting, and the left-hand anode goes to the more positive condition. This rise in plate voltage is coupled to the grid of the cathode follower section of V205 which provides a low-impedance match for the long shielded lead. The corresponding rise in cathode voltage is transmitted to the plate of the diode clipper and to the suppressor grid of the signal gate, V204, which remains open as long as V207 is in the right-hand-side-conducting condition. C210 improves the response time of the cathode follower, while the diode clipper prevents overshoot and holds the suppressor of the 6AS6 close to ground potential. R222 is added to speed the closing of the gate. On the second pulse from the time base, V207 is triggered to its original state, closing the signal gate, V204, and delivering a driving pulse to V208. This binary then triggers from the left-hand to the right-hand conducting condition, causing the suppressor grid of V206 to become negative and thereby preventing further amplification of pulses from the time base.

Automatic reset. - Both plates of the latching binary are connected to the grid of V209, the left-hand anode through a resistance divider and the series timing resistors, R254 and R255, and the right-hand anode through R248 and a 0.5 μf capacitor, C220. Initially, V209 is cut off. When the latching binary triggers to its second state, the right-hadd anode goes negative, and since the voltage across C220 cannot change rapidly, the grid of V209 will go negative a similar amount. As the charge ont the capactior leaks off through the timing resistors, the grid potential of V209 increases, the final value being above cut-off. When this occurs, plate current flows through the reset relay, K201. The normally closed contact of this relay is then opened and the two binaries, V207 and V208, are reset. As long as the relay is open, the latching binary will be held in the left-hand conducting state and the right-hand anode will be at its most positive potential. C220 is recharged through the grid and the diode-connected half of V209, and when fully charged, the grid voltage drops to a value such that the plate current of the relay tube is cut off. This allows the relay contact to close and leaves the instrument ready to start another counting cycle. The time interval between the triggering of the latching binary to the right-hand conducting state and the opening of the reset relay is the display period of the unit. A small interval of time is required after the display period for the resetting operation. The display time is continuously variable from less than one second to about eight seconds, depending on the adjustment of R255 by the operator (see Figure 11).

The previous discussion has been based on the assumption that the unit was switched to the AUTO position of switch S204, the EPUT position of S202, and the OFF position of the count switch, S203. If the unit is switched to the MANUAL position, the operation is identical, with the exception that the automatic reset circuit is not used but resetting is performed manually by pressing the pushbutton RESET switch, S205. Since the operation of the unit is entirely dependent on the two binaries, the RESET switch also serves as a starting switch. Placing S202 in the COUNTER position closes the time base gate, and if S203 is now turned ON, the signal gate suppressor grid is grounded and the signal gate remains open, allowing the EPUT to function as a conventional counter.

Power supply. - The power supply is designed to furnish +310 volts, +180 volts regulated, and -150 volts bias as well as 6.3 volts a-c both to the instrument and to the accessory socket, J101. A special circuit consisting of the cathode-follower half of V202 is used to provide a low impedance screen supply to the gate tubes, V204 and V206 (see Figure 12).



NOTE:
RESISTERS:
WATTAGE——$\frac{1}{2}$ WATT UNLESS OTHERWISE NOTED.
TOLERANCE——5% UNLESS OTHERWISE NOTED.
CAPACITORS:
CAPACITY——IN μμf UNLESS OTHERWISE NOTED.
VOLTAGE RATING-500V " " "
TOLERANCE——15% "
ALL VOLTAGES MEASURED WITH VTVM WITH COUNT AT "0".

C-020-401933-Rev. M
April 1962

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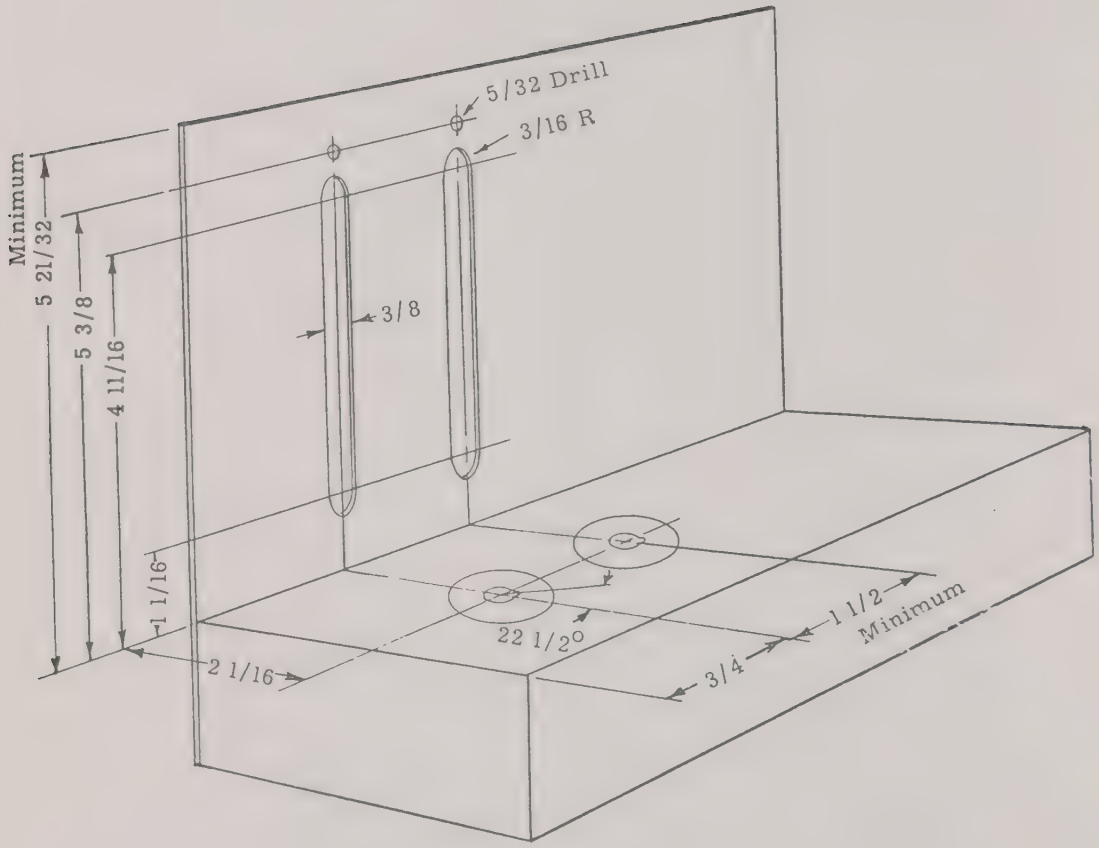
Figure 6 Schematic Diagram Model 705A



NOTE: Dimensions are based on the use of an Amphenol "MIP" 8 or 11-pin socket mounted above the chassis.

The drawing shows chassis dimensions for mounting two Model 705A DCU's side by side. All modifications of the Model 705A (705AH, 705AF, etc.) have precisely the same dimensions as the standard 705A.

Mounting Dimensions, Model 705A and All Modifications Thereof

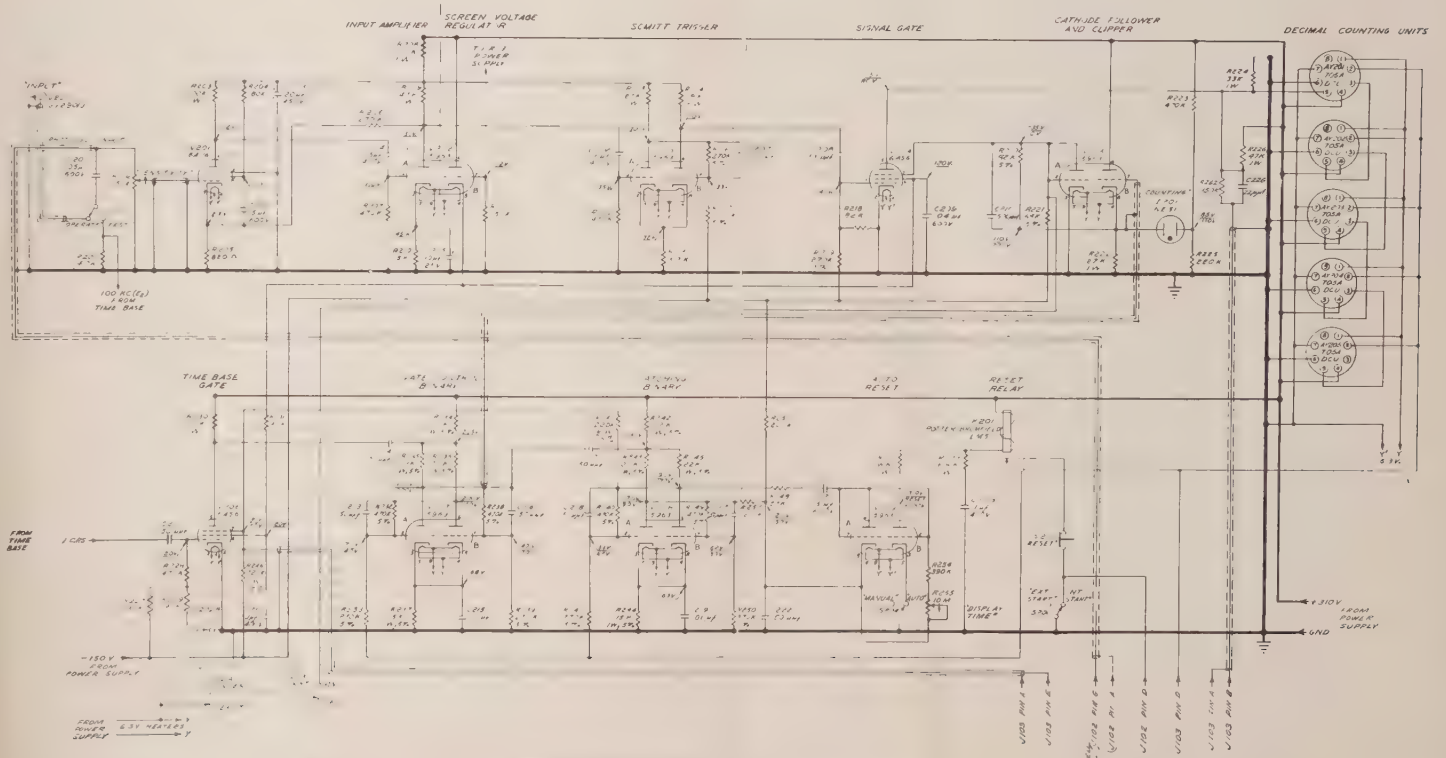
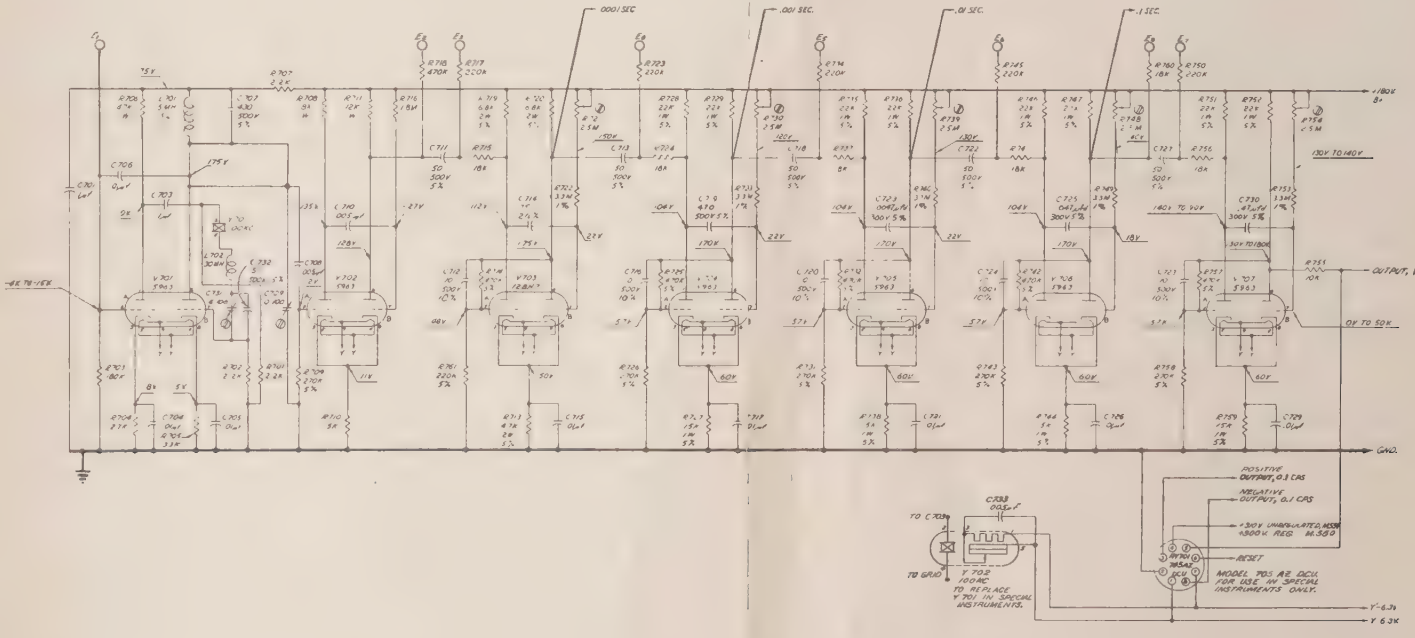


Figure 11 Schematic Diagram, Model 554



NOTE
1. RESISTORS ½ W, ± 10% UNLESS SPECIFIED
2. CAPACITORS 600V, ± 20% UNLESS SPECIFIED
3. CAPACITOR VALUES ARE IN μf UNLESS SPECIFIED
4. AC VOLTAGES MEASURED WITH A RMS VOLTMETER

Figure 9 Schematic Diagram, Model 505 Time Base

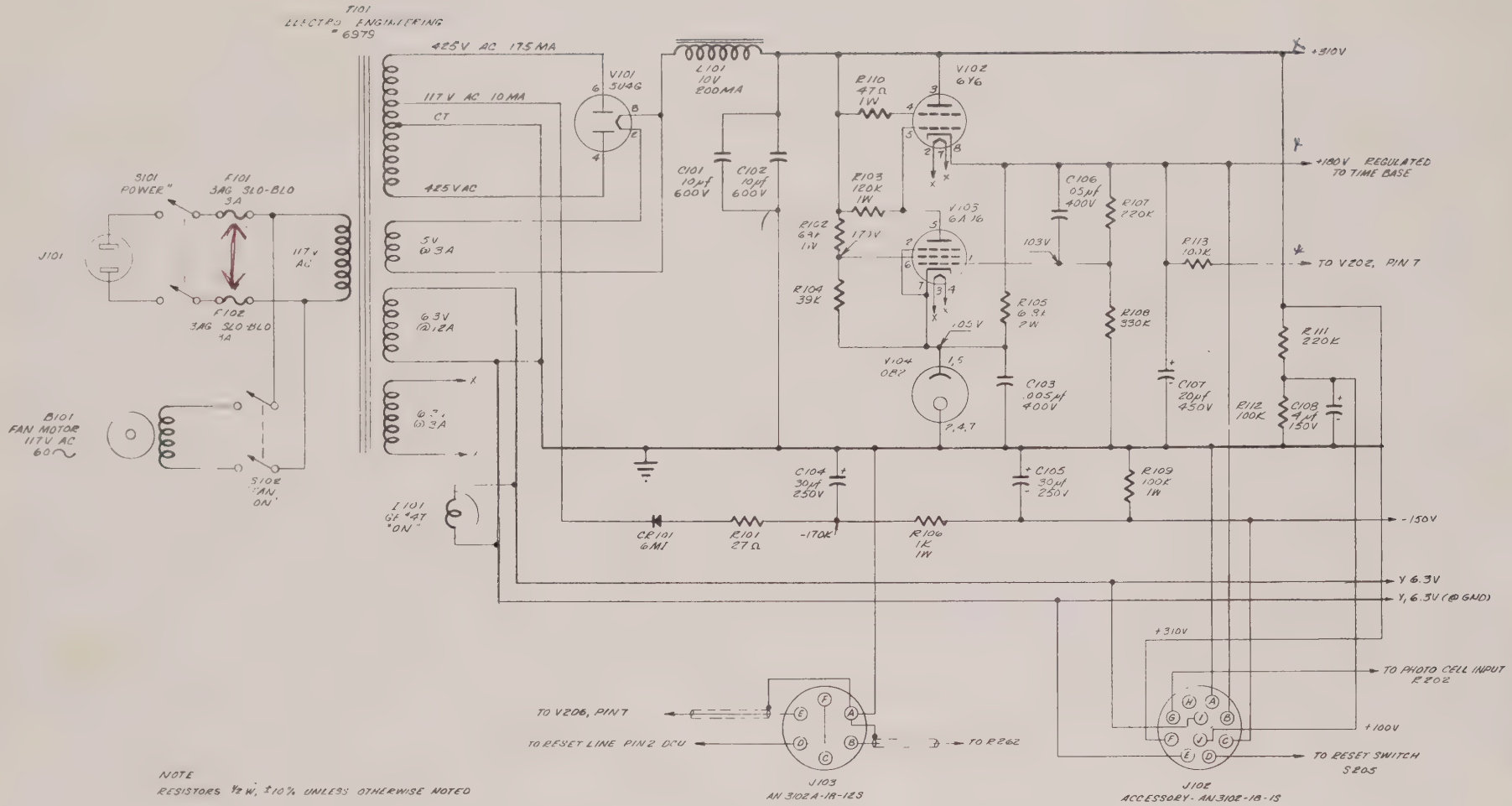


Figure 10 Power Supply Schematic

Section 4
MAINTENANCE

Routine Servicing

Since the entire device operates on the principle of the existence or non-existence of discrete pulses, changes of tube or compnnent characteristics within normal limits have little effect on the operation. Therefore the equipment should require little or no servicing. The only routine adjustments required occur in the time base.

Oscillator frequency (see Figure 13). - Whenever the crystal is replaced, the following procedure is recommended to ensure a 100 kc frequency output from the oscillator. A secondary 100 kc standard source is necessary.

a. Place a high impedance VTVM on pin 2 of V701 to measure the grid bias developed.

b. Adjust the PLATE TUNE (C709) for maximum bias.

c. Connect the secondary standard to one of the axes of an oscilloscope and connect the other axis to test point E2. This will isolate the oscillator from the measuring circuits.

d. Adjust FREQ. VER. (C731) until the Lissajous figure indicates that the frequencies are matched.

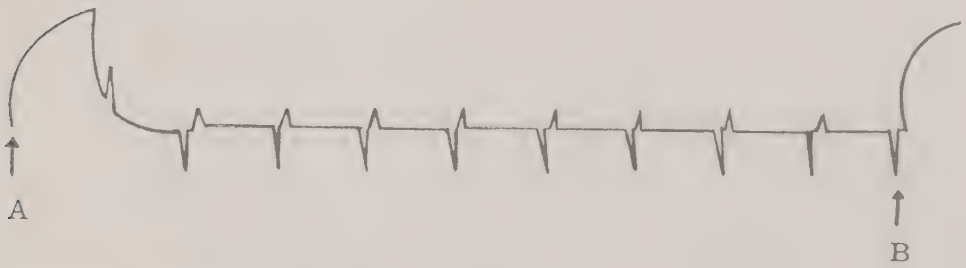
Frequency dividers (see Figure 13). - There are two methods for adjustment of the frequency dividers. One method requires an oscilloscope with a 10 megohm input impedance and at least a 500 kc bandwidth, while the other requires only a pair of slip-leads and a 50 $\mu\mu$f coupling capacitor.

a. Oscilloscope method. (Unit in TEST)

Place the input probe on test point E3, with the oscilloscope sweep set at approximately 100 μsec. The screwdriver adjustment, 1ST DIV. (R721) should be turned until the pattern shown below (or its inversion) appears on the oscilloscope.

Note that there are 10 visible, positive excursions from point A to point B. Make sure that the potentiometer is set near the middle of the division-by-ten range.

Connect the oscilloscope to test point E4 and set the sweep for 1000 μsecs. Adjust the 2nd DIV. (R730) so that the following pattern appears on the oscilloscope.



Note that the proper pattern shows only nine negative excursions between points A and B, the tenth being hidden by the large pulse as indicated by the arrows. This same pattern will be observed at E4, E5, #6 and E7 when the corresponding dividers are dividing properly. Since the pattern at E7 is rather difficult to see on the oscilloscope because of the slow recurrence rate, it is best to adjust the last divider by observing the DCU reading on the front panel.

To make sure that the dividers are near the center of their operating range and thereby guard against errors due to line-voltage fluctuations, the following procedure is advisable. Connect the EPUT to a variable power source, such as a Variac or similar auto-transformer, and place in TEST. Lower the line voltage to about 105 volts, adjusting the dividers until the reading on the DCU's is correct. Do the same for 130 volts.

The dividers can be adjusted to a point where line voltage variations between 105 and 130 volts will not cause errors in frequency division.

b. "50 $\mu\mu$f" method.

Set the unit in the TEST position!

A 50 $\mu\mu$f capacitor is connected from the input grid of the time base gate (pin 1, V206) to the output of the second divider (pin 6, V704). The first and second divider potentiometers are adjusted until a count of 100 is obtained on the DCU's.

In turn, connect the clip lead to pins 6 of the third, fourth and fifth dividers, and adjust the particular dividers so that readings of 1000, 10, 000 and 100, 000 are obtained, respectively.

The testing and maintenance of the Decimal Counting Units is described in Appendix A.

Trouble-Shooting*

Table 3, the Trouble-Shooting Chart, lists some of the more frequent failures and their causes. Waveforms shown in Figures 9 and 10 should also be consulted.

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*All testing should be preformed with a VTVM and an 11-megohm input-impedance oscilloscope.

Table 3

TROUBLESHOOTING CHART

Failure	Trouble	Possible Causes
Power supply failure (see Figure 12.)	Absence of unregulated B+.	a. Bad 5U4G. b. Transformer T101 open. Replace. c. L101 open. Replace. d. Short from B+ to ground. Eliminate. e. Broken lead between power supply and front chassis. This may be checked by testing at the tie point strips located on the extreme right-hand side of each chassis.
	Absence of regulated B+ to time base.	a. V104, OB2 not fired, or V103 or V102 have failed. Replace. b. C103, C106, or C107 are leaky or shorted. Replace.
	Oscillations on regulated B+.	a. V102, 6Y6 oscillating, Replace. b. V104 unstable. Replace.
	Absence of unregulated negative supply voltage.	CR101, 6M1 selenium rectifier may have failed. Note any arcing of this component. If a short has occurred, R101 (27Ω, 1/2 watt) will be burned. Replace.
In TEST, the DCU's do not read 00000	Incorrect division by one or more of the dividers	Follow the procedures given earlier in this section for divider alignment. If on adjustment of a particular divider, it is found that the division ratio suddenly skips non-sequentially (e. g. from division by 9 to division by 12), the trouble usually is with the potentiometer concerned.

Table 3 (cont'd)

		Replace the faulty potentiometer. Also check the cross-over timing condenser of the stage.
	One divider does not divide.	Drive from the previous stage is faulty. Replace the tube involved. When the unit reads 99000 it is usually one of the first four dividers that is off.
In TEST, the readings are incorrect and inconsistent.	One divider jitters. The waveform will look like the one shown.	Move the potentiometer to make sure that it is not set midway between the two division ratios. The trouble may also be caused by the next stage even though the next stage waveform looks proper. Replace the tube of the stage that jitters and the one following. If this does not correct the trouble, check the voltage around the malfunctioning stage.
	One of the dividers is acting as a free-running multivibrator.	Check voltages at each divider and compare with voltages shown on the schematic. Change the tube in the stage concerned. Make sure that the regulated supply is free from ripple.
EPUT will not cycle on either AUTO or MANUAL	Condenser C709 has become shorted due to a small piece of metal lodging between its plates. This will cause R707 to char and break.	Replace R707 after making sure that the short is removed by rotating the plates of C709 with an ohmmeter placed across it.

Table 3 (cont'd)

Failure	Trouble	Possible Causes
	Coil L701, 5 mh, is open and therefore no voltage appears at pin 6, V701. This coil may be open at either end.	A turn can be taken off, and the wire re-soldered.
	The time base gate, V206, doesn't pass time base signals.	Examine the voltage at the input of C211 to see that it varies between the values indicated on the output of the time base schematic (Fig. 13) Check the voltage at pins 1, 2, 5 and 6 of V206. Next examine the voltage at pin 7. This should be zero when the reset is depressed. If it is not examine the latching binary, V208 (see below).
	One of the gating circuit binaries has failed.	Check the voltages at the various pins and check them against those given on the schematic. Replace binary if necessary.
	The contacts of relay K201 are not making contact.	Burnish the contacts.
	One of the binaries is running free.	This is most likely due to a component or tube failure in one of the binary circuits. All voltages should be examined, especially grid-to-cathode voltages. If this voltage is low, the Binary may have a tendency to run free. Be sure that the loads are not coupling back any interference into the binaries, and triggering them.

Table 3 (cont'd)

Unit cycles properly but does not count.	The trouble lies somewhere in V201, V202, V203, V204 and the associated circuitry. Also the SENSITIVITY control may be adjusted to too low a value.	Check the differentiated output of the Schmitt at pin 1 of the signal gate, V204 using an oscilloscope. The waveshape should look as shown.
		Note the diode clipping of the positive section of the wave. This is evidence that the signal gate is drawing grid current. Then check the voltages against those shown on the schematic.
	Signal gate is not driving the Model 705A DCU or the DCU itself is at fault. (If the latter is the case, see the DCU sections at the rear of this manual.)	Check all the voltages against those shown on the schematic. This will usually show where the trouble lies The voltage on pin 7 should vary between -35 volts and zero. The amplitude of the negative voltage is not important as long as it is greater than 20 volts, but during the other condition, the grid should be zero or slightly positive. Change to 6AS6, V204.

Section 5
PARTS LIST

List of Non-Standard Components

Detail No.	Stock No.	Item	Mfr. & No.	Description
T101	2151	Power transformer	Electro 6979	
K201	2168	Relay	Potter-Brumfield	LM5 (5000 ohm coil)
I201	1679	Pilot Lamp	G. E. NE-51	Indicator lamp
I202	1677	Pilot Lamp	G. E. #47	Indicator lamp
B101	1821	Fan motor	Barber-Coleman	DYAB 569-2
	1822A	Fan blades	Barber-Coleman	YAB 32'8
J101	1665	Receptacle	Cannon	AN3102-18-1S
J103	17-2713	Connector	Cannon	AN3102A-18-12S (Printer)
J201	0849	Connector	IPC 2700	
S101	1642	Switch	Cutler-Hammer 8370K8	DPST toggle
S102	1643	Switch	Cutler-Hammer 8370K8	SPST toggle
S201	1641	Switch	Cutler-Hammer 8282K13	SPDT toggle
S202	1909	Switch	Cutler-Hammer 8373-K7	DPDT toggle
S203		Same as S102		
S204		Same as S102		
S205	1614	Switch	A. H. & H. #3391	Push-button
S206		Same as S102		
*Y701	0458A	Crystal	Valpey - XL	100 kc
L101	0366	Choke	U. T.C. CG40	
L701	1509	Choke	Miller 650	5 mh
L702	2422	RF Choke	Miller 692	30 mh, 120 ohm maximum
F101 & F102	7-0504A	Fuse		3 AG, Slo-Blo, 3 ampere

* Modifications D and F use a James Knights crystal, 100 kc, T-9 in JK5 oven, Stock No. 13-2245.

Tube List

Tube	No. Required Per Unit	
5U4G	1	(V101)
6AU6	2	(V103, V201)
6Y6	1	(V102)
OB2	1	(V104)
6X4	1	(V105)
5963	11	(V202, V203, V205, V207, V208, (V701, V702, V704, V705, V706, V707)
5965	1	(V209)
6AS6	2	(V204, V206)
12BH7	1	(V703)
2D21	1	(V210)

Section 6
MODIFICATIONS*

Modification A

Modification A adds the following features to a standard Model 554:

(a) A 6-digit mechanical register which extends the counting range to ten digits. The operation of the register is explained under Modification J.

(b) A selective 0.1, 1.0 and 10 second Unit Time Base which is explained under Modification B.

Modification B

The UNIT TIME switch provides selective 0.1, 1.0 or 10 second unit time bases. Figure 13 shows the 0.1 and 1.0 second outputs from the fourth and fifth division-by-ten stages. The 10 second time base is shown as the output of the 705AZ Decimal Counting Unit, which is used as a sixth divider. The Model 705AZ is described in Appendix B.

Modification D

As a frequency standard, an over-heated, highly stable crystal is used. The oven temperature tolerance is $\pm 1^{0}$ C., with panel indication of oven heating. Stability approaches one part in one million. The crystal is a James Knight T-9 mounted in a JK-5 oven.

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* In modified instruments the diagram for the modification has been included in the rear of the manual rather than the standard diagram. Such diagrams are designated by a letter following the figure number. For example, the schematic for Modification A will be marked Figure 11A.

Modification F

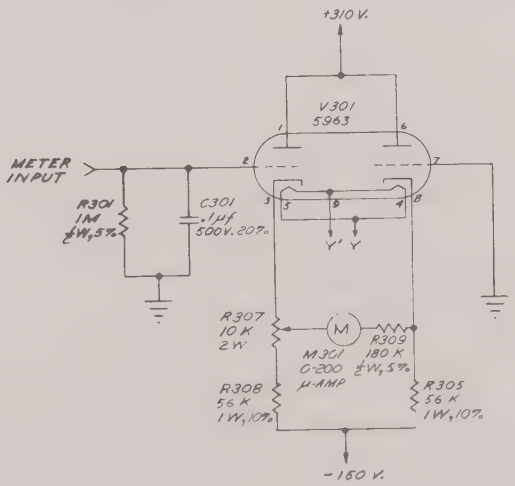
Modification F adds:

(a) A selective 0.1, 1.0 and 10 second Unit Time Base, as described under Modification B.

(b) An oven-heated crystal, as described under Modification D.

(c) A front panel voltmeter to facilitate setting of the sensitivity level by inexperienced operators. Sensitivity should be adjusted so that the meter pointer is in the green area of the scale.

Assuming a 50-50 input duty cycle, the DC level at the input of the Schmitt Trigger V203 should be -35 volts. This voltage causes the meter to read in the green portion because of unbalance in the cathode circuits of V301 (shown below). The potentiometer R307 is used to zero set the voltmeter under no input conditions.



Modification G

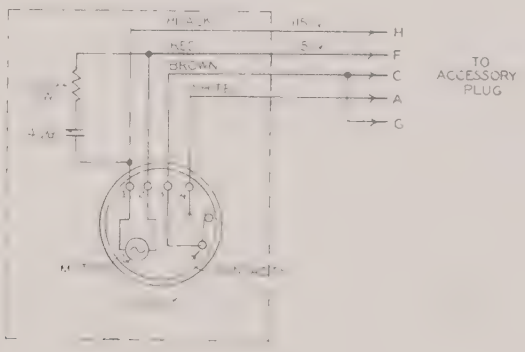
Accessory socket output connections and the separate Model 804 Time Delay Unit permit automatic counting at any time base multiple from 3 to 60 seconds. Accuracy is equal to that for standard units.

Operation with Model 804 :

1. Connect the Model 804 to the accessory socket and set the dial to one-half second less than the time interval desired.

2. Set the COUNTER-EPUT switch at COUNTER, the COUNT switch OFF, and the UNIT TIME switch at 1 SECOND.

3. Counting initiates both the EPUT and the Model 804 clock. The EPUT stop pulses are held off until the clock reaches the end of its cycle. The succeeding stop pulse ends the period, displays the count, and resets the clock. EPUT reset may be either automatic or manual.

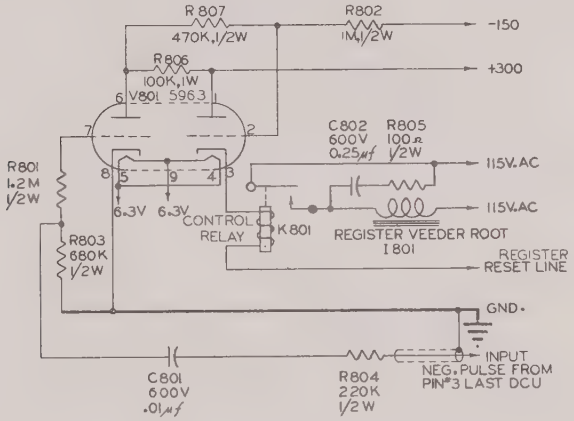


CLOCK : R.W. CRAMER CO.
TYPE TE 60 S - WD 260
TIME DELAY RELAY
ADJUSTABLE TO 60 SECONDS
MOTOR : SYNCHRONOUS
CONTACTS : NORMALLY OPEN (MOTOR OFF)

Timing control originates at the control grid of the time base gate. Normally, this grid is connected through resistors to ground. However, in Modification G the grid is grounded through the normally closed contacts of K202. K202 is actuated when the gate control binary flips to the ON state. This breaks the ground, corcing the time base grid to cut off, and simultaneously applies power to the clock (see figure). The clock runs until its contacts close, grounding the grid and allowing the succeeding time base pulse to stop the EPUT.

Modification J

A six digit mechanical register to extend the counting range to ten digits is added.



The register and register drive are diagrammed above. Negative pulses from the last DCU are applied to the left-hand grid of V801, causing the left-hand triode to cut off. This in turn applies a positive bias to the grid of the right-hand side, causing it to conduct and activate the control relay, K801. Closure of the control relay contacts applies line voltage to the stepping type register, which advances one count. Meanwhile, the left-hand grid returns to the ON condition and cuts off the right-hand side. This releases the control relay and opens the register circuit again.

The control relay is connected to ground through a contact on the RESET switch. This contact must break before the DCU reset line contact breaks when the unit resets. This sequence prevents spurious DCU pulses caused by resetting from actuating the register.

Modification K

Instruments of the 554K type have a maximum sensitivity of five millivolts RMS between 5 and 1,000 cycles. Sensitivity falls to 50 millivolts at the

upper frequency limit, 100 kc. The Model 554K is used to monitor the output frequency of standard Potter Aeronautical Flow Meters.

The power supply provides a -105 volt regulated supply (see Figure 12K). The input amplifier section has the standard tubes, but is modified in other components and in its B+ return (see Figure 11K).

Bothe the input amplifier and time base are supplied with 150 volts, which may be adjusted by the potentiometer on the power supply chassis (R117). The triggering point of the Schmitt trigger depends on this voltage. At 150 volts the Schmitt triggers on a slight positive voltage. Reducing this voltage will increase the instrument's sensitivity, but will make it more susceptible to drift, line transients, and hum.

Owing to the increased input time constants necessary for low frequency response, the Model 554K is subject to blocking. Incorrect readings may occur if the input pulses vary greatly in amplitude, or if their amplitude suddenly decreases.

Modification T

The following special features are added to the Model 554T:

(a) One-half second time base.

(b) Neon extinguishing provision during count.

(c) Optional explosion proof housing.

(d) Means for operation with the DCU's externally placed in a Model 1940 Remote Indicator.

The one-half second time base permits counting and display periods of a half-second each, with a one-second sampling rate. This is done by division-by-five instead of by ten in the last divider.

To facilitate recording of data by the operator, the indicator lamps on the Decimal Counting Units are extinguished during the counting period by applying +100 volts to pin 8 of all DCU's during the counting period. The extinguishing circuit, V210, provides this voltage because of its

zero biased grid. The grid is tied to the suppressor grid of the time base gate (V206), which in turn is controlled by the state of the latching binary. Both grids are driven to cutoff when the latch flips at the end of the count. The open circuit through the extinguishing tube allows the neon lamps to indicate normally during the display period. The extinguishing feature is not used when the instrument is used as a straightforward counter. In the COUNTING position, the extinguishing voltage is removed. When the unit is used as an events-per-unit-time meter, the COUNT switch should be off.

An explosion-proof housing for the instrument permits safe operation in a potentially explosive atmosphere. Construction is in accordance with MIL-E-15136 specifications. The sealed housing completely encloses the "EPUT" Meter denying access to all connections and controls except the accessory and input cables.

The 554T is one component of the 554T-1 Remote Tachometer Indicator System. Other instruments in the System are the Model 1950X Remote Indicator (external DCU housing) and the Model 460X Tachometer Pickup, either of which can be used separately with the Model 554T.

The 1940X contains four DCU's, one less than the normal number when used within the "EPUT" Meter. It may be driven at distances up to 100 feet through RG-62/U cable (92 ohm) and a special network in the signal gate circuit of the 554T. The network provides impedance matching and frequency response compensation necessary for the remote drive. A transient damping network is added to the 554T reset line to avoid spurious DCU signals during reset. Standard cable length is 20 feet.

Modification P

This modification adds read-out circuitry to the "EPUT" Meter so that the accumulated count may be introduced to a Berkeley Model 1452 Digital Recorder in the form of a four-line binary code from each DCU. The Model 705A DCU's are replaced by Model 705AFM DCU's which have a read-out socket on the DCU chassis. The four lines from each DCU are gathered together at a 40-terminal cannon socket at the rear of the Model

554 which mates with a plug on the Model 1452. The necessary mutual control connections between the "EPUT" Meter and the Model 1452 are made by connecting terminals at the rear of the ground DIGITAL RECORDER socket on the rear lip of the counter to the proper terminals on the added Cannon socket. Pin 8 of each Model 705AFM plug is connected to the -150 volt supply source.

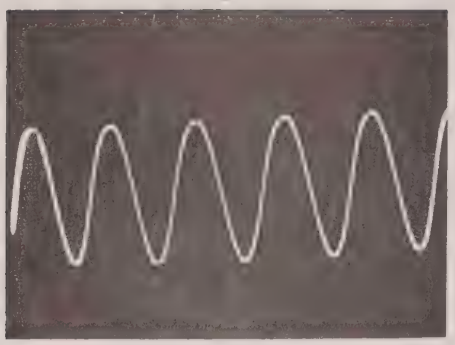
The schematic diagram of the Model 554P shows these changes incorporated in a standard instrument. If the instrument this manual accompanies has been modified in other ways also, the Model 554P schematic should be consulted only for information on Modification P.

Connections between the DCU readout sockets and the Cannon connector socket are as follows:

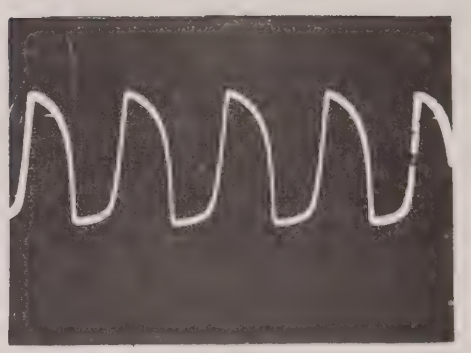
DCU	DCU Readout Socket Pin	Model 1452 Connector Terminal
AY 201	A	24
	B	23
	C	22
	D	21
AY 202	A	20
	B	19
	C	18
	D	17
AY 203	A	16
	B	15
	C	14
	D	13
AY 204	A	12
	B	11
	C	10
	D	9
AY 205	A	8
	B	7
	C	6
	D	5

NOTE

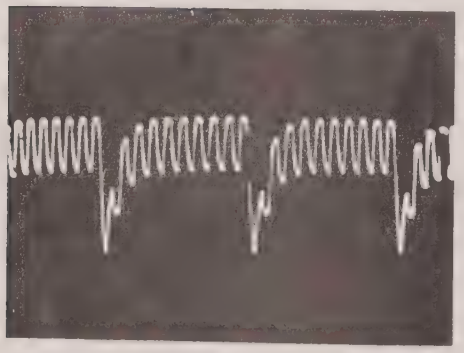
The following waveshapes were photographed with a 4x5 Speedgraphic Camera A Model 511A Tektronix oscilloscope was used.



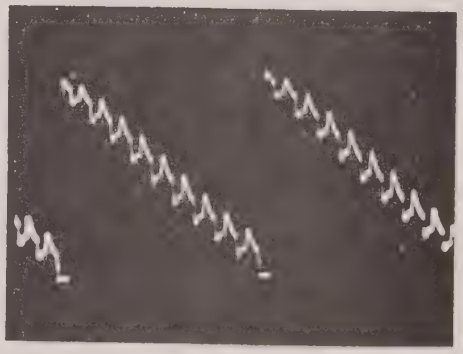
A. V701, pin 6, 100KC sine wave oscillator output, 35 volts amplitude.



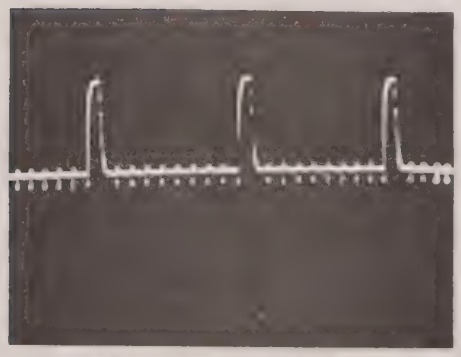
B. V702, pin 6, output pulse, shaping circuit.



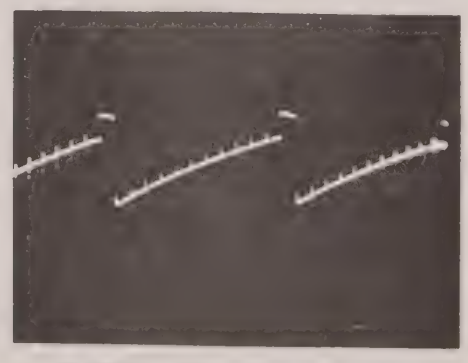
C. Test point E3, peak to peak amplitude 30 volts, 100μsec between maximum peaks.



D. V703, pin 7, peak to peak amplitude 50 volts,.

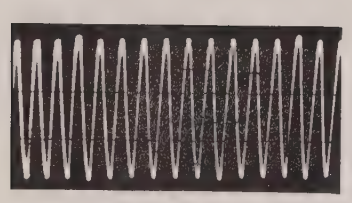


E. [illegible]

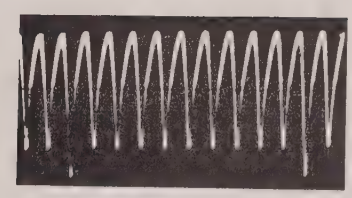


F. [illegible]

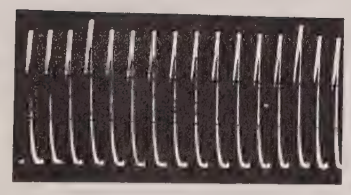
Figure 9. - Typical Waveforms, Model 505 Time Base



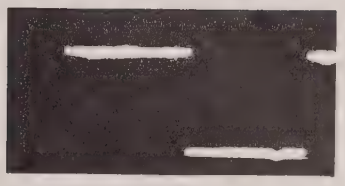
A. V201 Pin 5
Output, First Input Amplifier
Freq.: 100 kc
Amplitude: 12 v. peak-to-peak



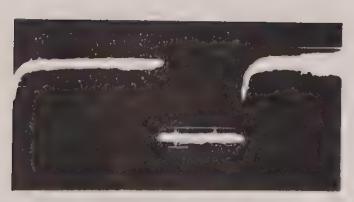
B. V202 Pin 1
Output, Second Amplifier
Freq.: 100 kc
Amplitude: 125 v. peak-to-peak



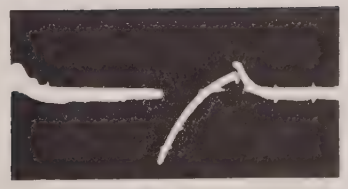
C. V203 Pin 6
Output, Schmitt Trigger
Freq.: 100 kc
Amplitude: 130 v. p-p max.



D. V207 Pin 1
Output, Gate Control Binary
Positive pulse duration: 1 sec.
Amplitude: 100 v. p-p



E. V208 Pin 6
Output, Latching Binary
Negative pulse duration =
Display Time
Amplitude: 75 v. p-p



F. V209 Pin 1
Grid waveform of Auto Reset
Period of exponential rise =
Display Time

Figure 10, Typical Waveforms, Model 554

Lot 27 and up
Appendix A

MODEL 705A

DECIMAL COUNTING UNIT

Berkeley division of
BECKMAN Instruments, Inc.

Richmond, California
1 May 1954

WARRANTY

Instruments sold by Berkeley Division, Beckman Instruments, Inc., (hereafter called "the Company") are warranted only as stated below.

Subject to the exceptions and upon the conditions specified below, the Company agrees to correct, either by repair, or, at its election, by replacement, any defect of material or workmanship which develops within one year after delivery of the instrument to the original purchaser by the Company or by an authorized representative, provided that investigation and factory inspection by the Company discloses that such defect developed under normal and proper use.

The exceptions and conditions mentioned above are the following:

(a) Some components and accessories by their nature are not intended to, and will not, function one year. If any such component or accessory manufactured by the Company and part of the item sold fails to give reasonable service for a reasonable period of time, the Company will, at its election, replace or repair such component or accessory. What constitutes reasonable service and what constitutes a reasonable period of time shall be determined solely by the Company after the Company is in posession of all the facts concerning operating conditions and other pertinent factors and after such component or accessory has been returned to the Company, transportation prepaid.

(b) All instruments claimed defective must be returned to the Company, transportation charges prepaid, and will be returned to the customer with the transportation charges collect, unless the item is found to be defective in which case the Company will pay all transportation charges.

(c) The Company makes no warranty concerning components or accessories not manufactured by it, such as tubes, fuses, batteries, etc. However, in the event of the failure of any component or accessory not manufactured by the Company, the Company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.

(d) Except as stated above, the Company makes no warranty, express or implied (either in fact or by operation of law), statutory or otherwise; and, except to the extent stated above, the Company shall have no liability under any warranty, express or implied (either in fact or by operation of law), statutory or otherwise.

(e) The Company expressly disclaims any liability to its customers, dealers, and to users of its products, and to any other person or persons for consequential damages of any kind and from any cause whatsoever arising out of or in any way connected with the manufacture, sale, repair, replacement of, or arising out of or in any way connected with the use of any of its products.

(f) Representations and warranties made by any person, including representatives of the Company, which are inconsistent or in conflict with the terms of this warranty (including but not limited to the limitation of the liability of the Company as set forth above) shall not be binding upon the Company unless reduced to writing and approved by an officer of the Company.

(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate. Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, Berkeley division of Beckman Instruments, Inc., Richmond 4, California.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

Berkeley reserves the right to make changes in design at any time without incurring any obligation to modify equipment previously purchased to conform to subsequent design changes.

BERKELEY DIVISION
BECKMAN INSTRUMENTS, INC.

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Figure 1 Model 705A Decimal Counting Unit

Section 1
INTRODUCTION

The Model 705A Decimal Counting Unit (DCU) is a direct reading, plug-in electronic counter. The number of counts received is indicated by the illumination of one of ten neon lamps placed behind a numbered acetate panel. Each unit counts from zero to nine, the tenth pulse resetting the counter to zero and simultaneously generating an output signal. Any number of units can be connected in cascade (the output of one unit driving the next) to form a counter whose total capacity depends only on the number of DCU's. Thus, five units will count to 99, 999 and reset to 00,000 on the 100, 000th pulse.

Specifications

Count Indication	Direct Reading Decimal presentation
Power Requirements	Heater: 6.3 v. at 1.2 amps Plates: 300 v. at 15 ma.
Input Requirements recommended	Negative pulse 100 volts peak amplitude
Rise Time	Less than 1 μsecond
Duration	At least 2 μseconds
Output Characteristics	Designed to drive a Model 700A, 705A, or 707A
Resolution of Paired Pulses	5 μseconds
Reset to Zero	Instantaneous through opening of grid return
Maximum Counting Rate	100, 000 cps
Construction	Plug-in unit octal socket
Dimensions	1-3/8" x 5-1/2" x 5-1/2"
Weight	1 lb.
Tubes	Four type 5963

Section 2

OPERATION

Installation

Normally, Decimal Counting Units are installed in Berkeley instruments. No special instructions are necessary. For unusual installations, we invite your inquiry.

Operation

Power requirements:

Plates: 225 to 400 volts (nominal 300 volts at 15 ma.)
Filaments: 6.3 volts at 1.2 amperes.

Input requirements:

If the Model 705A is powered by an unregulated supply, the drive amplitude should vary with the supply voltage. A negative transient is required to drive the unit, either a square wave or a rectangular pulse at least 2 microseconds wide. The pulse amplitude depends on the rise time. For a rise time of 0.5 microseconds (measured between ten and ninety percent values), the pulse amplitude should be between 75 and 135 volts; for a 2 microsecond rise time, an amplitude of 120 to 165 volts should be used. Rise times of 1 microsecond or less, pulse amplitudes of 100 volts, and a 300 volt supply offer optimum performance. The input load presented by either unit during triggering is equivalent to 100 $\mu\mu$f in series with 15,000 ohms.

Output requirements:

The output is a rectangular waveform presented at the output terminal as a change in d-c voltage (see Figure 4). Between "0" and "6", the output is 55 volts; "6" and "7", 125 volts; and "8" and "9", 135 volts. The step between "7" and "8" is caused by an interpolation network.

The load imposed on either unit must not be more than 300 K to ground or 6 K in series 100 $\mu\mu$f.

Section 3
THEORY OF OPERATION

Basic Design

The basic circuit of the Model 705A is a modification of the Eccles-Jordan trigger circuit with two stable states, referred to as a binary. It is a two-stage amplifier with the output of the second stage connected to the input of the first, as shown in Figure 2.

With no input, the loop gain is less than one, and the circuit is in one of its two stable states, i.e., either V2 conducting and V1 cut off, or vice-versa. The circuit is triggered from one state to the other by making the loop gain greater than one. The binary is coupled to a single trigger source through C1 and R1 in such a way that the effect of the trigger is different on the two stages, depending on which stage is conducting. For example assume that V2 is conducting and V1 is cut off. If a negative pulse is applied to the input, there is a drop in the plate voltage of V1. This drop in voltage is transmitted through the cross-over network (R5, R8, C3 and the grid-to-ground capacitance of V2) and applied to the grid of V2. The plate voltage of V2 then starts to rise, carrying with it the grid of V1. When the input pulse is of sufficient amplitude, the loop gain becomes greater than one, and the binary is triggered to its other stable state, V1 conducting the V2 cut off. The next input pulse reverses the process and causes the binary to return to its original state. Thus, the binary completes a cycle for every two input triggers, and is a scale of two. By a cascade arrangement of binaries, a counter having a scale of any power of two can be obtained.

Circuit Analysis

Four binaries are connected in cascade forming a scale of 16, which is permuted to a scale of 10 by two resistor-capacitor "feedback" networks (see Figure 3).

The circuit operates as a conventional binary counter up to the count of four. On the count of four the third stage is triggered, sending a pulse through the first feedback network, thereby triggering the second stage. Since it requires two inputs to trigger the second stage, this is the equivalent of adding two input pulses and the unit now corresponds to a binary count of six. On the count of six (which is the equivalent of eight in a binary counter) the fourth stage is triggered, sending a pulse through the second "feedback" network and triggering the third stage. This is the same result as if four additional input pulses had been applied and the unit has a binary

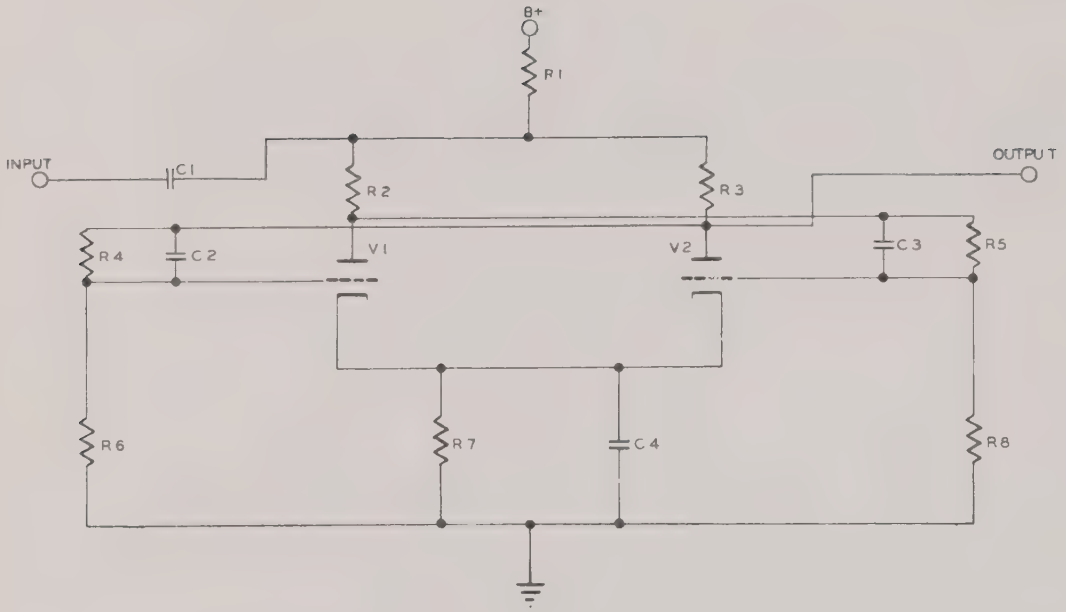


Figure 2 Basic Circuit

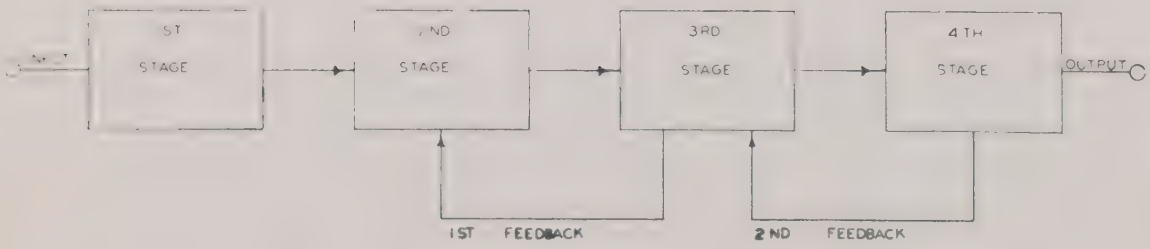


Figure 3 Functional Diagram

count of twelve stored in it. The unit again operates as a binary scaler for the remaining four pulses required to reset it to zero. Therefore, by adding the equivalent of six input pulses, the scale-of-16 has been permuted into a scale-of-10.

Section 4
MAINTENANCE

When a Decimal Counting Unit is suspected of counting incorrectly, it should be interchanged with another unit in the instrument or replaced with a spare unit to determine whether the trouble is in the suspected unit or in the associated circuitry. This test should be made very carefully. Since the counting unit is usually the indicating device of a larger instrument, faulty operation is often ascribed to it when the symptoms of external faults are displayed.

Troubleshooting

Two methods are recommended for finding the trouble in a faulty counting unit. First, by observing the lighting sequence while driving the unit at a slow repetition rate, and second, by studying the waveform of each stage while driving the unit at a repetition rate fast enough to be conveniently viewed on an oscilloscope. It is impossible to say which method should be used in every case, since marginal failures may occur at high counting speeds and not at lower counting rates, and vice versa. The first method is the only way that a neon lamp failure can be located, and it can be used to locate component and tube failures. For this reason, it is recommended that this method be used first. Table 1 lists common troubles. Faulty tubes cause most failures.

Diagrams and Tables

Typical waveforms are shown in Figure 4. By comparing these with the waveforms from a defective unit, the faulty stage can be quickly detected. Table 2 lists the voltages and resistances between tube socket connections and ground so that in conjunction with the schematics and parts location diagrams all information necessary to maintain the equipment in proper working order is available It should be remembered that the values given are nominal, and considerable variations may be encountered owing to various line voltage conditions and component tolerances.

Circuit drawings and parts location diagrams will be found at the rear of the manual. The voltages shown were obtained with a vacuum tube voltmeter, a supply voltage of 300 volts, and measured between ground and the point indicated The unit must be reset to zero to obtain the values shown

Table 1
COMMON TROUBLES*

Symptom	Cause
Unit Fails to Count	(a) Insufficient supply voltage. (b) Input signal of insufficient amplitude. (c) Input signal of wrong polarity (d) First stage inoperative.
Unit Counts Spuriously	(a) Stray output signal. (b) Pulses received through power supply. (c) External voltages picked up by output lead.
Unit Counts Erratically	(a) Input signal too large or small, incorrect rise time. (b) Supply voltage fluctuating too much.
Unit Fails to Reset	(a) Stray counts from reset switch or associated circuitry. (b) Defective component
Unit Counts in Wrong Sequence (the pattern of lighting is repeated after a definite number of input pulses. One or more lights may be "On" simultaneously during a cycle provided that the number of states per cycle remains constant).	
1. Unit skips every other number.	(a) First stage defective. (b) Input circuit supplies double pulses.
2. Two stable states per cycle.	(a) Second stage defective (count can be 01 or 45). (b) Loss of drive to second stage (01).
3. Four stable states per cycle.	(a) Third stage defective (count can be 0123 or 6789). (b) Loss of drive to third stage (0123).

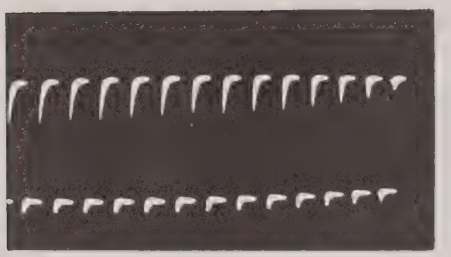
4. Six stable states per cycle.	(a) Output excessively loaded (count can be 012345-012345). (b) Last stage inoperative (count can be 01234501 etc. or $67\overset{89}{23}89$. The count $\overset{8}{2}$ indicates both "8" and "2" lamps are on. (c) Loss of drive to fourth stage (count can be 012345).
5. Eight stable states per cycle or any failure where two successive numbers are skipped.	(a) Second or third stage failure.
6. Ten stable states per cycle, but the lighting sequence is incorrect.	(a) Where the "0" neon lamp lights instead of the "4", the trouble is with either the "0" or "4" lamp, and in the majority of cases it is "4". This can happen on any count; zero and four were used as examples. It is also possible that more than one lamp may light in place of, or with the one that fails.
7. Twelve stable states per cycle.	(a) When lighting sequence is $\overset{01}{0}12345456789\text{-}0$, etc. (The count 4 indicates both "0" and "4" lamps are on). First feedback failure. Second or third stage losing emission. (b) When the lighting sequence is $\overset{23}{0}12345678989\text{-}0$, etc. Second feedback failure. Third or fourth stage losing emission.

* Reset Unit before troubleshooting.

Table 2
MODEL 705A - VOLTAGES & RESISTANCES

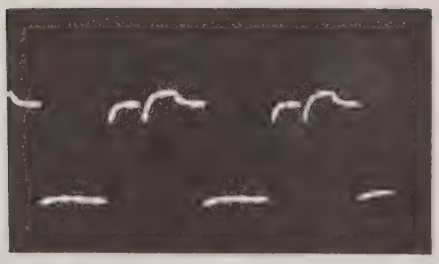
Tube	Pin No.	D. C. Voltage to Ground	Resistance to * Ground (in ohms)
V101	1	170	105K
	2	17	85K
	3, 8	37	12K
	4, 5, 9	Filaments	
	6	60	105K
	7	37	85K
V102	1	135	93K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	93K
	7	30	83K
V103	1	135	100K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	100K
	7	30	83K
V104	1	135	93K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	93K
	7	30	83K

* When making the above resistance measurements on a DCU with an octal plug, connect pin 2 to pin 6. On a DCU with an 11 pin plug, connect pin 3 to pin 8.

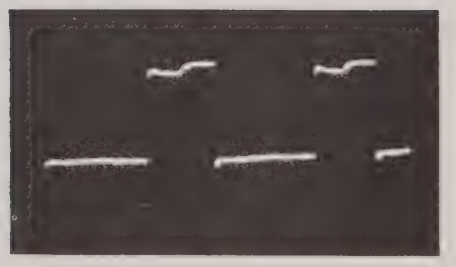


A. First Stage, Pin 6, V101, UVL + 168, LVL + 58, frequency 20Kc.

B. Second Stage, Pin 6, V102, UVL + 140, LVL + 55, frequency 20 Kc.

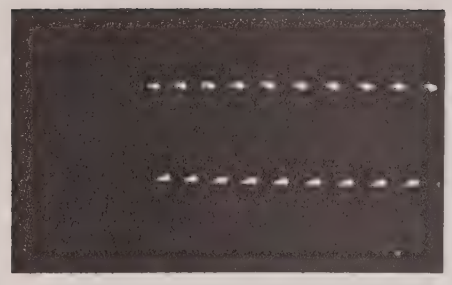


C. Third Stage, Pin 6, V103, UVL + 140, LVL + 55, frequency 20 Kc.

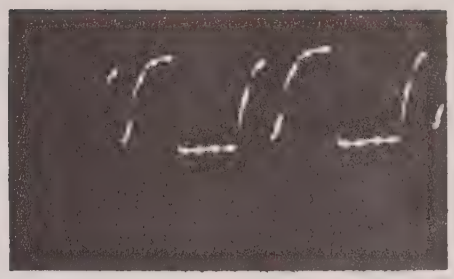


D. Fourth Stage, Pin 6, V104, UVL + 140, LVL + 55, frequency 20Kc.

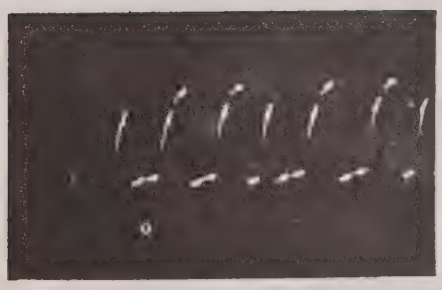
Figure 4 Typical Waveforms



E. First Stage, Pin 6, V101, UVL + 168, LVL + 58, frequency 100Kc.



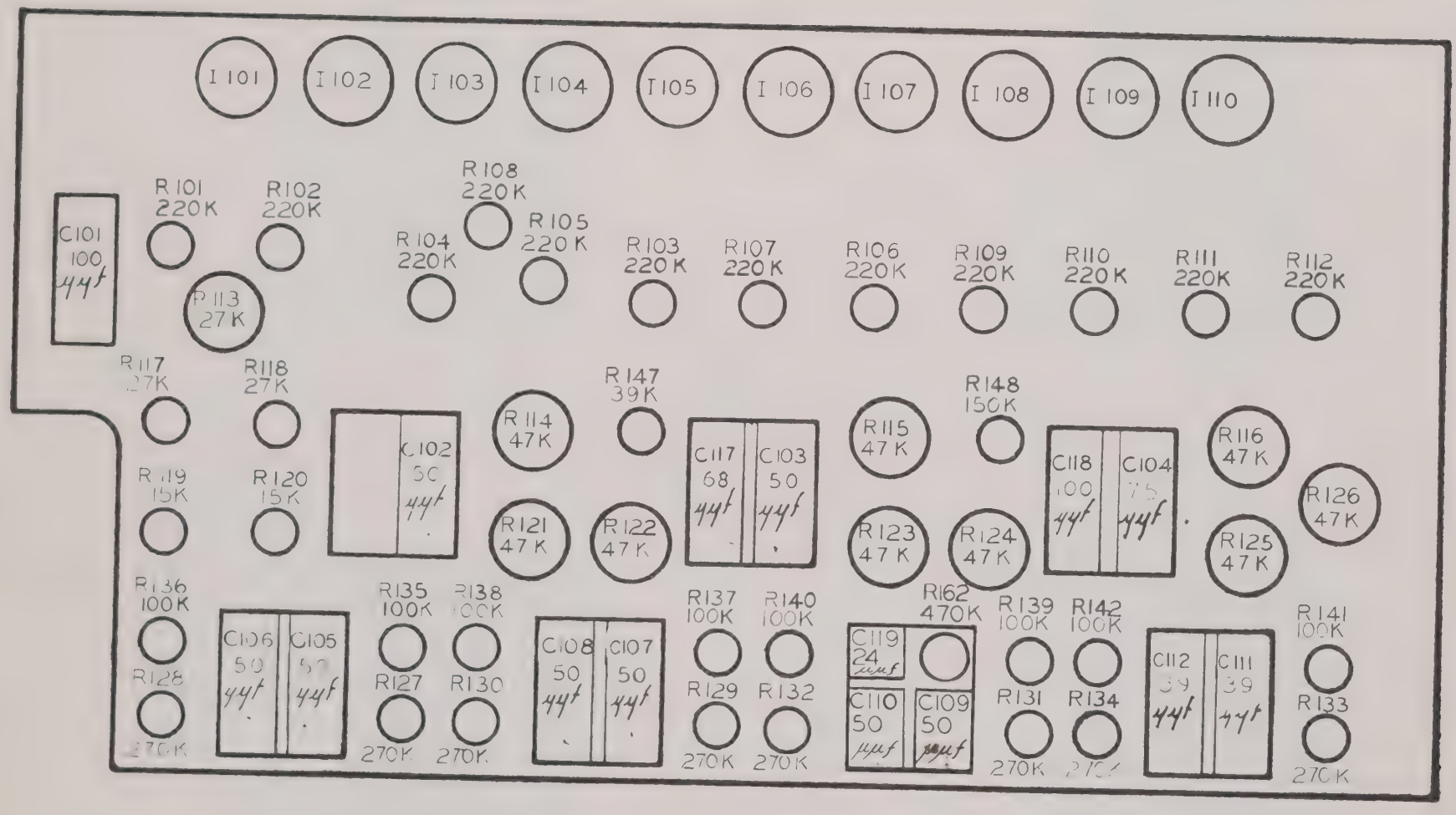
F. Second Stage, Pin 6, V102, UVL 140, LVL + 55, frequency 100Kc.



G. Third Stage, Pin 6, V103, UVL + 140, LVL + 55, frequency 100Kc.

H. Fourth Stage, Pin 6, V104, UVL + 140, LVL + 55, frequency 100 Kc.

Note: UVL = upper voltage level
LVL = lower voltage level
All waveforms are blanked.



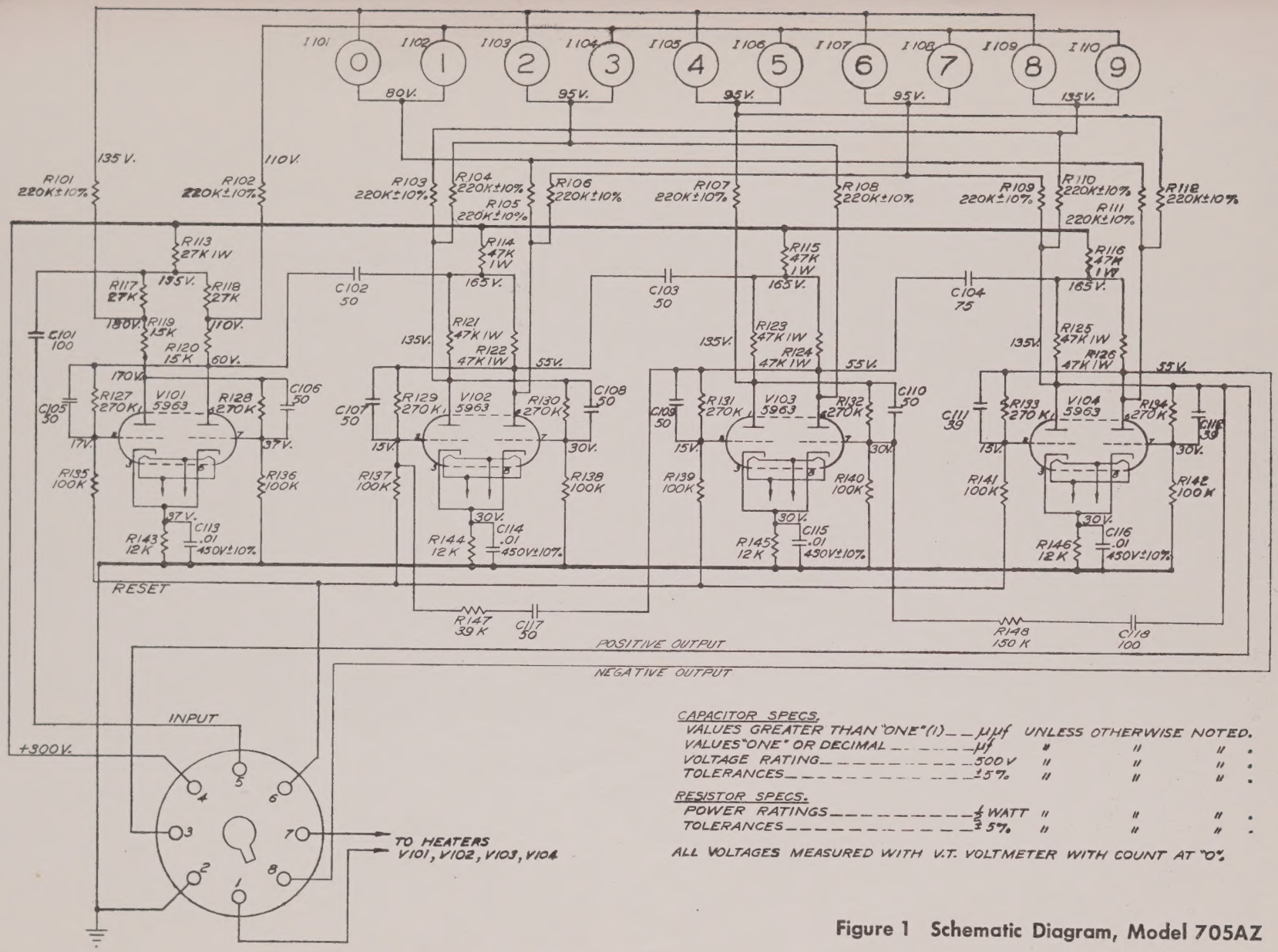
Parts Layout

The Model 705AZ, Decimal Counting Unit, has been designed especially for use as a scale-of-ten extension to time bases. Its schematic is essentially that of the 705A, except for two modifications (see Figure 1).

1. The voltage on the second plate of the last binary (pin 1 of V104) is led out to pin 3 of the DCU socket. Pin 8 on the DCU socket is connected to pin 6 on V104.

2. The 705AZ is returned to the "nine" condition by the RESET control. This is done by connecting the reset line.

A DCU reset at "nine" requires only one input count to generate an output and commence a new timing cycle. A DCU reset at "zero" would require ten input counts before transmitting a Start pulse to the gating circuitry.



CAPACITOR SPECS.
VALUES GREATER THAN "ONE" (1) ___ μμf UNLESS OTHERWISE NOTED.
VALUES "ONE" OR DECIMAL ___ μf " " " .
VOLTAGE RATING ___ 500 V " " " .
TOLERANCES ___ ±5% " " " .

RESISTOR SPECS.
POWER RATINGS ___ ½ WATT " " " .
TOLERANCES ___ ±5% " " " .

ALL VOLTAGES MEASURED WITH V.T. VOLTMETER WITH COUNT AT "0".

Figure 1 Schematic Diagram, Model 705AZ